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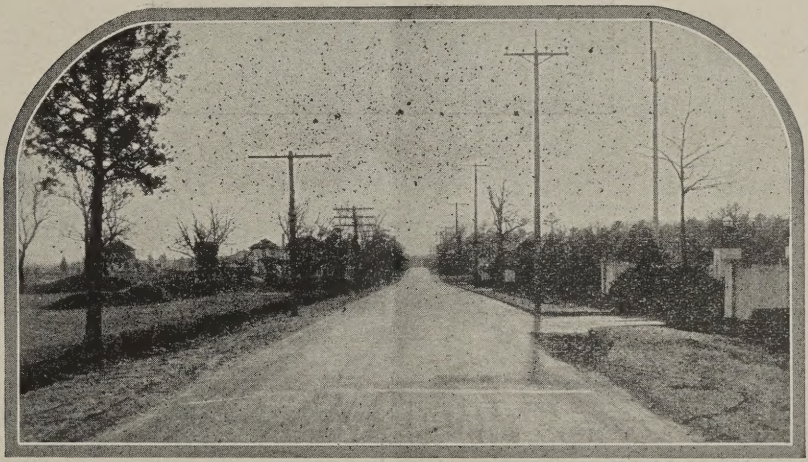


In front of Seaview Golf Club, near Atlantic City, (Route 4)

Note

The papers presented at the last Convention of the New Jersey Highway Association, and the discussions following them, are such a valuable contribution to the progress of road-building that it has been decided to publish them in full with as many as possible of the charts and illustrations used. (It has not been possible to include all of these, however, so there are occasional references in the text, to photographs and charts which have not been reproduced).

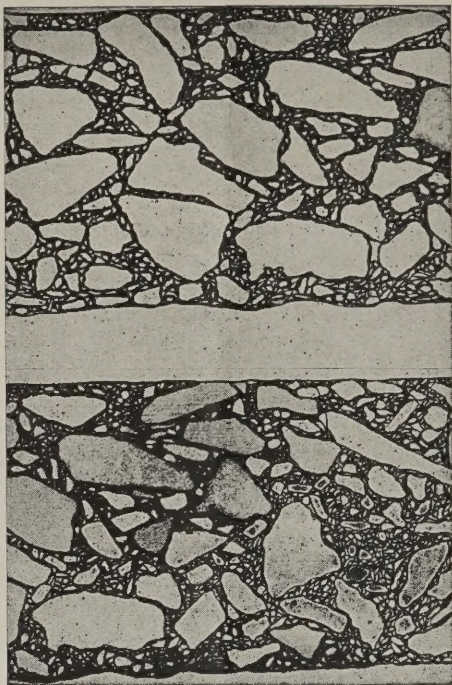
Our aim is to publish one or two of the Convention papers, with the discussion thereon, each month. We suggest that these be carefully filed, so that the reader may keep the complete set, which will make a very valuable addition to his road-building library.

This month we are printing "The Advantages Secured by Sealing a Bituminous Concrete Pavement with a Hot Sand Mixture", by G. H. Perkins, M. E., Warren Bros. Co., and the discussion thereon at the convention; also "Proper Methods to Follow in the Control of Paving Mixtures", by H. S. Mattimore, Engineer of Tests, Pennsylvania State Highway Department, and the discussion thereon at the convention; and Contract News.

Next month there will be published, "Proper Use of Highway Literature", by Charles E. Murphy, Texas Company; "Care and Handling of Highway Equipment", by A. M. Cawley, Lakewood Engineering Co., and the discussion thereon at the convention; "The Use of Explosives in Road Building", by N. S. Greensfelder, Hercules Powder Co., and Contract News.

Early Years

Max. of Stone
Min. of Mortar
Max. of Stability



(Cuts ¾ actual size)

Later Years

Stone Decreased
Mortar Increased
Stability Decreased

The Advantages Secured by Sealing a Bituminous Concrete Pavement with a Hot Sand Mixture

By G. H. Perkins. M. E.

The title of the subject which has been assigned to me, viz.: "The Advantages Secured by Sealing a Bituminous Concrete Pavement with a Hot Sand Mixture," brings up at once four pertinent questions—

1st. Is it necessary to seal the surface of a properly designed bituminous concrete?
2nd. Can it be sealed with "a hot sand mixture"?
3rd. If it is necessary and possible, how can this be done?
4th In what respects is the final product an improvement over prior construction?

On account of our long familiarity with bituminous concrete such as Bitulithic and with the dense asphaltic concrete binder and sand mixtures used in sheet asphalt construction, these questions appear extremely simple; however, in evolving our answers, we must be careful to *think clearly* or we shall be led astray by the similarity in appearance of products which are actually radically different in both structure and physical characteristics.

In reply to our first question as to whether a properly designed and constructed bituminous concrete needs to have its surface sealed, let us review the history of the Bitulithic pavement which was not only the best known bituminous concrete, but also the one which received the most study.

F. J. Warren Invention

When F. J. Warren invented this pavement he found that by properly proportioning the amounts used of the various sizes of aggregate from coarse to fine, he produced an aggregate which contained a very low percentage of voids, possessed "inherent stability" and required much less bituminous cement than was necessary in sand mixtures.

The increased stability of the *aggregate* was caused by two factors, first the interlocking of the coarser with the smaller particles, second the greater inertia of the large particles of stone or gravel used, it being manifest that greater force is required to move a 1 in. stone than a grain of sand.

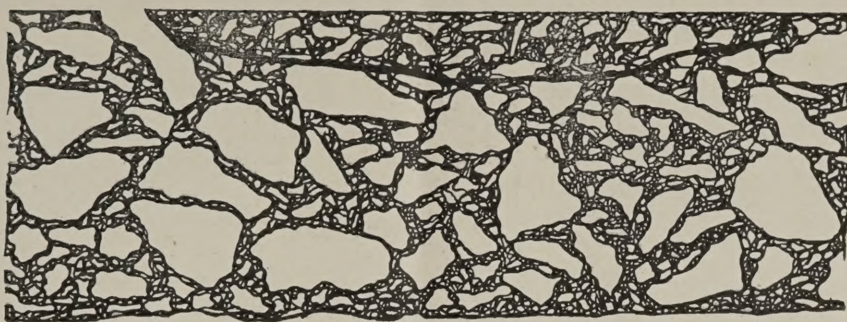
The stability of the *pavement as a whole* was also governed by two factors, viz., the inherent stability of the aggregate and the proportion of bituminous cement used in the mixture, because, while the particles of stone, gravel, or sand are unaffected by any change in temperature to which the pavement is subjected, and these particles are individually as rigid in hot as in cold weather, the bituminous cement is very susceptible to temperature changes, and in hot weather becomes plastic, consequently as the physical characteristics of the completed pavement must be a composite of the characteristics of its component parts, it was obvious that the stability of the pavement would be increased by keeping the percentage of the mortar element composed of fine aggregate and bituminous cement down to the minimum amount required to fill the spaces between the larger stones.

The early Bitulithic pavements were designed upon this basis.

Necessity of Flushcoat

When these mixtures were spread and compressed it was found that the surface contained small pores in the mortar between the uppermost stones and that it was necessary to seal these pores with liquid bitumen known as "flushcoat," then in order to prevent the flushcoat bitumen from adhering to wheels of vehicles it was necessary to roll stone chips or coarse sand into this thin film of bitumen. It was, of course, appreciated that these stone chips or hard particles of coarse sand when rolled, actually perforated the film of bitumen, changing it from one contiuous waterproof sheet to literally a fine mesh sieve, with a stone chip placed in each hole of the sieve; however, at that time, it was believed that the freedom from voids and the stability of the aggregate were all that were needed and the advocates of the pavement adopted the slogan—"THE STONE TAKES THE WEAR."

No more truthful—no more unfortunate slogan—could have been adopted, because the bituminous mat formed by the flushcoat bitumen and chips was very short lived, soon



SKIM-PATCH
Bonded to but not Blended with Old Pavement
(Cut ¾ Size)

wore off, and when this happened, the exposed surfaces of most of the uppermost stones were seen to be fractured, allowing water to enter and start disintegration.

Early Design

The diagram is intended to show the basic design of these early pavements in which it will be seen that there is a minimum of fine mortar and a maximum amount of interlocking of the medium and largest sized stones. These pavements were so excessively rigid that the stones exposed at the surface of the pavement were soon more or less shattered by traffic; those which were completely shattered would be displaced, thus removing lateral support from adjacent stones, causing these to "ravel out" and form holes.

When a graded bituminous concrete mixture of this type is raked out loose upon the foundation, the upper surface of the loose layer contains an excess of coarse stones, there being little or no fine mortar visible. As the roller compacts the layer it pushes the stones down and these squeeze the mortar toward the surface. It was therefore suggested that if the mixture contained more fine aggregate mortar than that needed to just fill the spaces between the stones in the body of the pavement the excess would be brought to the surface by the roller and thus form a seal and protect the coarsest stones from the shattering effect of traffic.

This idea was put in practice at once and did to a very large extent reduce the amount of ravelling, but on the other hand introduced a new and equally serious difficulty.

Modified Design

Up to this point the proportioning of the aggregate could be determined by laboratory tests for voids, but as the amount of this excess mortar which would be brought to the surface by the roller depended upon so many factors such as the condition of the weather, temperature of the mixtures, etc., it was impossible to forecast how much of this excess would be brought to the surface by the roller and traffic and how much excess would remain down in the body of the pavement and thus spread the stones apart, as shown in the lower photo of this diagram (page 2). While this excess in the lower porton did of course act as a cushion for the stones and thus reduce the crushing effect of traffic, it seriously reduced the extent of interlocking of the particles and the stability of the pavement. It thus became an engineering problem to determine from a study of the road and its traffic conditions just how much excess mortar should be used in each case.

It was also obvious that while this compromise method produced more durable pavements, it could not be expected to produce a seal or protective covering for the uppermost stones, because when the mortar rose between the uppermost stones to the level of their tops, then the roller wheel would be supported partly by the stones, partly by the mortar, and both being subjected to the same pressure, the mortar would cease to rise, therefore it was still necessary to flushcoat the pavement, and as soon as the flushcoat bitumen was worn off by traffic, the upper surfaces of the stones were exposed to the elements and the abrasion of traffic as before.

Where such pavements were exposed to excessive moisture, re-flushcoating had to be resorted to at periodical intervals to prevent disintegration, the frequency of such treatment being dependent on the character of the stone used and traffic conditions.

In maintaining these streets and roads, Mr. E. C. Wallace who was in charge of bituminous mixtures for our company found that a ravelled spot or a depression could be repaired by painting the surface of the old pavement with a liquified asphaltic paint and then applying a layer of Bitulithic mixture containing an aggregate appropriate for the thickness of the so-called "skim patch."

In many cases these patches failed to adhere and peeled off in cold, wet, spring weather; others would shove into knots and waves; but many held in place, and wherever this occurred he noticed that such fine aggregate patches were more durable and more impervious to water than the surrounding coarse bituminous concrete surface.

Invention of Warrenite-Bitulithic

In 1909 Wallace was forced to resign on account of ill health and moved to California. While there he invented and patented what is now known as Warrenite-Bitulithic, thus furnishing the answer to our second and third questions, viz.: can a bituminous concrete pavement be sealed with a hot sand mixture and if so how can this be done?

From his observation of how the skim patches had acted on Bitulithic, he recognized that it was impossible to produce a successful pavement by first laying and compressing the bituminous concrete mixture, then laying thereupon a thin layer of fine mixture, as this would scale off or push and shove in the same way as a bituminous coating on a portland cement concrete pavement, and that in order to be at all permanent, this fine mixture must be an integral part of the pavement. In other words, he must produce *not a two layer* pavement but *a single layer* pavement, consisting of a coarse, rigid mixture in the lower portion and a compact, dense, fine mixture at the top, *so bonded together that there would be no plane of cleavage between the two.*

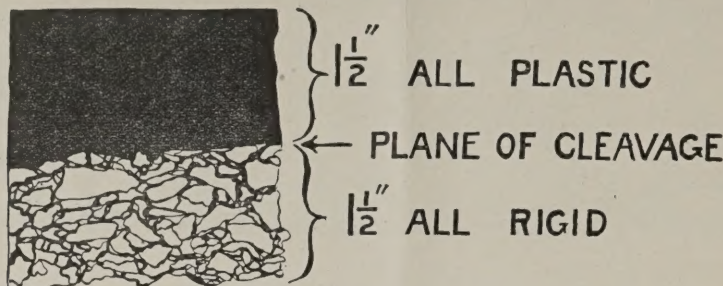
This then required the use of two dissimilar mixtures, laid separately, but combined by rolling into one single, compact, rigid layer.

His method provides that there shall be first spread upon the foundation a relatively thick layer of bituminous concrete mixture and while this is still in a malleable condition, cover it with a rich bituminous sand or fine aggregate mixture and by compressing the two together, thus blend the fine mixture with the top of the coarse mixture whereby the two layers are bonded into one.

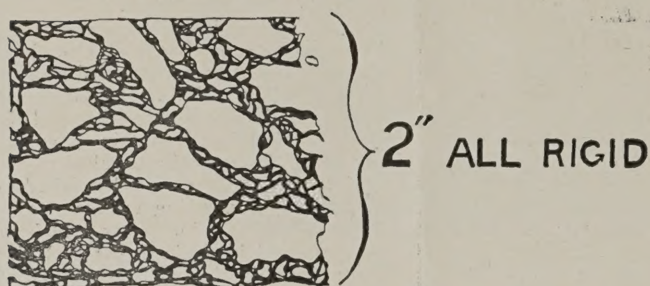
Departure from Prior Practice

In order to do this, it is of course necessary to apply the fine mixture before the coarse mixture has had time to chill appreciably, which means that a supply of both mixtures must be on the street at all times and be laid concurrently. It also means that the paving plant must produce one load of fine mixture after approximately every fourth load of coarse mixture. This was such a radical change from all past paving practice that when his patent was brought to our attention the construction men were unanimous in declaring the method impractical and impossible. Everyone claimed that the plant could not change back and forth from one mixture to another; that in laying sheet asphalt it was always necessary to run binder at least one-half day, then change to surface mixture, as is still the practice when laying that pavement.

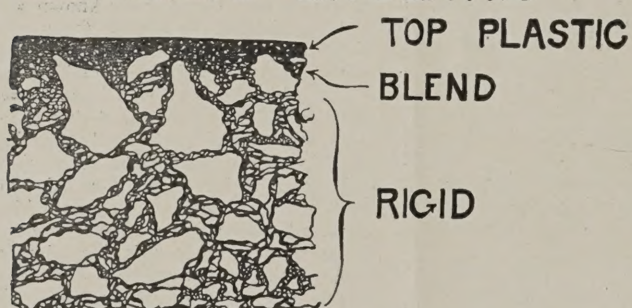
SHEET ASPHALT



BITULITHIC



WARRENITE-BITULITHIC



They claimed that the men on the street could not possibly handle two mixtures at once; that the fine mixture at the surface would act as a cushion and therefore the roller could not thoroughly compact the coarse mixture below; however, notwithstanding their prophecies, since 1910 we have laid 20,182,100 square yards of this pavement, equal to 1911 miles of roadway 18 feet wide, as shown by this table—all of which, as far as I know has been successful.

STATEMENT

To show total area in square yards of pavement laid in accordance with patents of E. C. Wallace under license granted by Warren Brothers Company and the ratio of same to the entire area of work laid under Warren Brothers Company license during the same period.

Year	Area Sq. Yards	Percentage
1910	874	0.3
1912	28,701	0.6
1913	16,250	0.3
1914	82,297	1.9
1915	298,425	6.6
1916	819,656	14.8
1917	1,529,770	29.3
1918	1,532,696	31.9
1919	3,021,296	40.4
1920	6,242,135	55.2
1921	6,610,000	87.5
Totals	20,182,100	31.8

Equivalent to 1911 miles roadway 18 feet wide.

The first work in 1910 in New Bedford, Mass., was a demonstration area under heavy cotton mill traffic. This was watched for two years, more was laid in 1912, and then in 1913 we started generally to substitute it for the older type. At first it was difficult to get people to change, but as time proved the superiority of the new construction its adoption became general as shown in preceding "Statement."

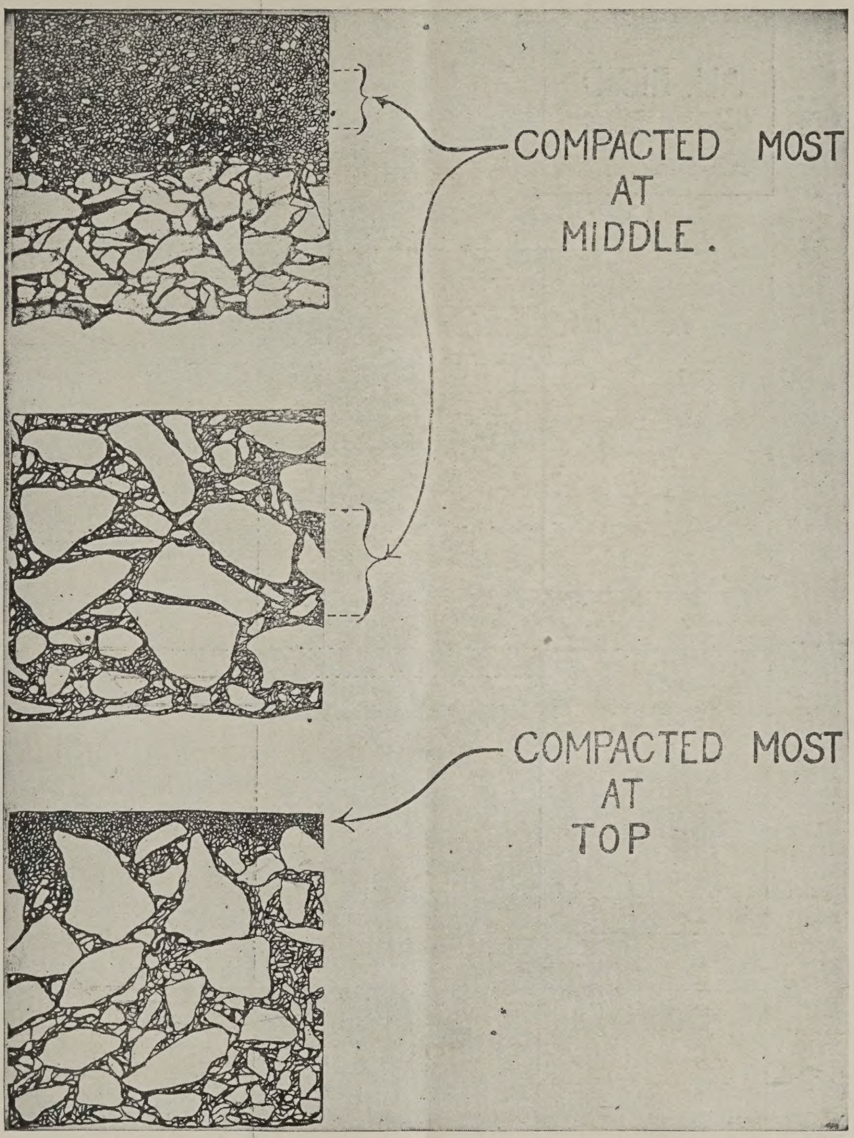
In answering our fourth and final question, *"In what respects is the final product an improvement over prior constructions?"* it is necessary to understand clearly the structure of the several pavements under consideration.

For convenient reference I am showing herewith enlarged photos of vertical cross sections of a standard sheet asphalt, a Bitulithic and a Warrenite-Bitulithic pavement, each of which is a typical sample of its type, taken from a street in actual use.

Comparison of Pavement Structures

By comparing these three pavements we find they are radically different in structure, as can be more plainly seen from the above diagram.

The sheet asphalt consists of two separate distinct layers of approximately equal thickness. Each layer is uniform in composition and therefore equally uniform in characteristics throughout its entire depth. The lower layer is *all rigid.* The upper layer is *all plastic.* There is a sharply defined irregular plane of cleavage between the two layers, which are bound together merely by the



cementing strength of the asphaltic coating on the uppermost stones of the binder course.

The Bitulithic is one single layer, uniform in composition and consequently in physical characteristics throughout its entire depth. *It is just as rigid at the top as at the bottom.*

The Warrenite-Bitulithic, however, is a structure, which when completed, is *not uniform* in composition or physical characteristics *throughout its depth;* which when completed is *not* composed of *two separate distinct layers* of dissimilar composition and characteristics; *but* on the other hand, *is one integral mass,* in which the *change* from the composition of the coarse mixture of the lower portion, to that of the fine mixture of the upper portion, *is not sudden,* but is a *gradual transition,* through the zone of blending, whereby the physical characteristics of rigidity and stability of the lower portion, *pass imperceptibly* into the plasticity and malleability of the uppermost portion.

A careful study of these differences in structure will explain the difference of results obtained under traffic if we will recall several fundamental facts, the importance of which is frequently forgotten.

Prior Pavements Most Compact at Middle

When compressing a layer of any bituminous mixture which is of uniform composition throughout the entire depth of the layer, such as sheet asphalt surface mixture, or a coarse aggregate bituminous concrete such as the original Bitulithic mixture, the layer will always be most compact at its center, and least compact at its upper surface.

If a newly laid mixture be sawed horizontally into three layers of equal thickness, you will find that the specific gravity or weight per cubic inch of the middle layer is the greatest, of the bottom layer next, and of the upper layer the least.

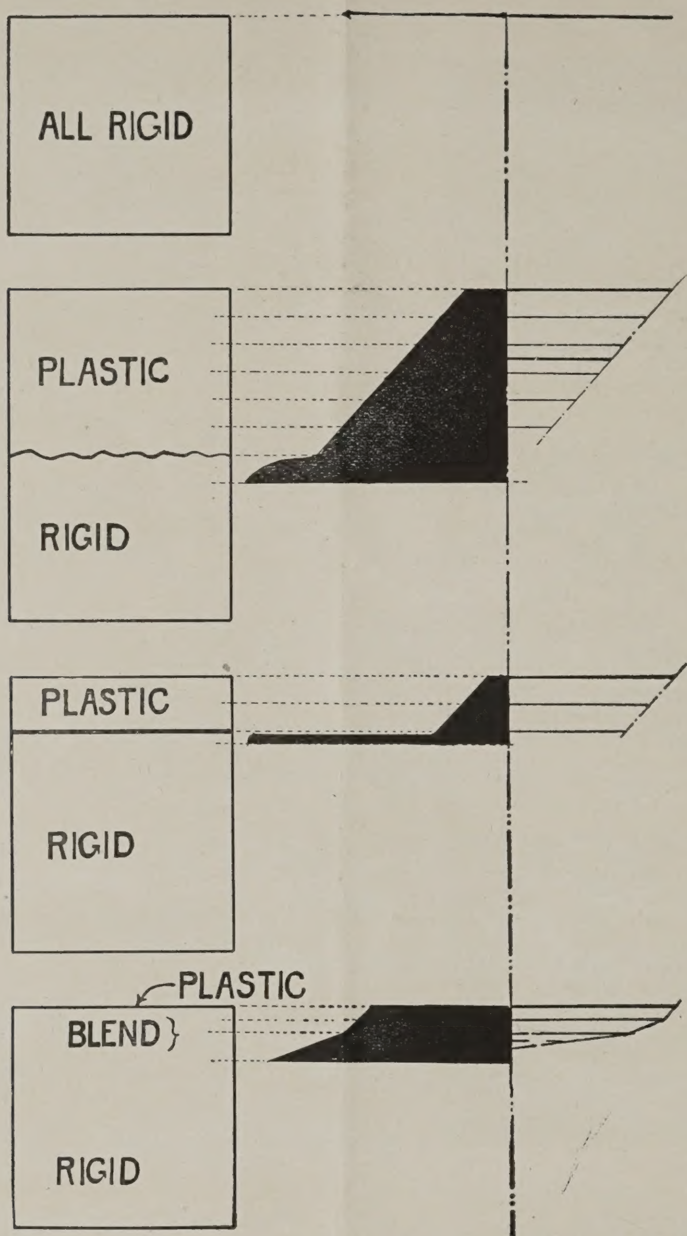
The reason for this is twofold, first, as action and reaction must be always equal, the foundation pushes upward with the same force that the roller pushes downward. These two forces meet at the middle of the layer. Second, the degree of compaction imparted to the mixture depends upon the length of time which the particles of aggregate are kneaded back and forth by the roller and as this kneading action can only take place while the asphalt cement is warm and plastic, naturally *the effect is greatest at the middle of the layer* because the surface is cooled rapidly by the atmosphere, the bottom of the layer cooled less rapidly by the foundation, but the middle of the layer cools extremely slowly and is therefore compacted most.

This is a most important fact and is one of the reasons why it is necessary to flushcoat a Bitulithic pavement and why it is customary to sweep dry portland cement over a compressed sheet asphalt surface.

In the cases just mentioned, as the character of the aggregate and relative proportions of aggregate and bituminous cement are the same throughout, the middle of the layer remains more malleable than top or bottom during the progress of the rolling *simply because of its temperature.*

Warrenite-Bitulithic Most Compact at Top

In the case of Warrenite-Bitulithic, however, *the conditions are entirely different,* because the layer is not of uniform composition throughout, and while the middle of the layer remains hot longer than either the surface or the



bottom, it must be remembered that the fine aggregate mixture at the surface is more malleable and plastic than the underlying coarse mixture, irrespective of such difference of temperature obtained under all except very extreme weather conditions.

When the roller first passes over the fine mixture it presses it down into the spaces between the uppermost stones of the coarse mixture; also whenever the fine mixture lies on top of a stone, the weight of the roller is transmitted to the stone and presses it down into the mixture. The foundation of course resists this pressure, or pushes upward as before, and the crowding of the stones together squeezes the fine mortar of the coarse mixture upward until it meets the fine mixture of the upper portion coming down. At that time the compaction or consolidation of the coarse mixture is complete and the lower and central portion of the structure is so rigid that the roller cannot force any more of the plastic fine surfacing mixture into it, therefore the kneading action of the final rolling must necessarily compact this fine mixture at the immediate surface to a far greater degree than it can compact the immediate surface of any other type of pavement, and therefore Warrenite-Bitulithic is the only bituminous pavement which at time of completion is compacted to a greater degree at the upper surface than at a lower depth.

Traffic Stresses

Moving traffic on any pavement tends to push the immediate upper surface ahead as well as sideways, and these stresses must be absorbed by the wearing surface section itself, or by it and the underlying binder course, or foundation.

In the accompanying diagram I have attempted to indicate how the results of such stresses are dependent upon the thickness as well as upon the character of the wearing surface layer.

The four blocks at the left of the diagram represent four distinct types of construction as follows:

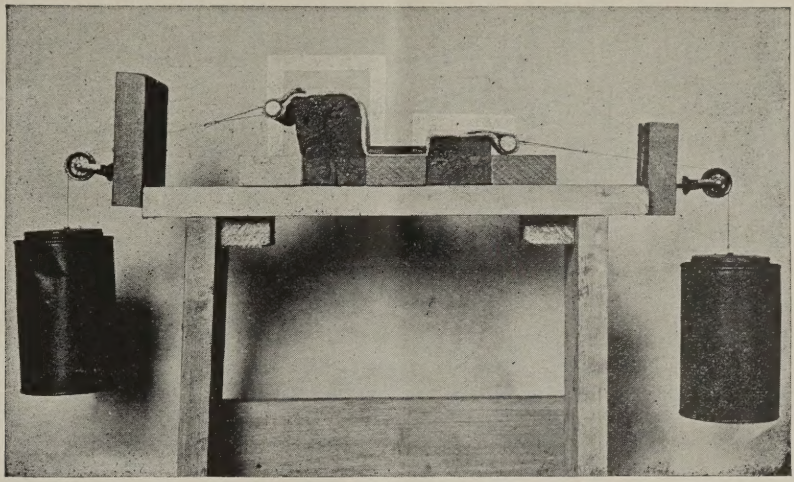
1st. Original Bitulithic=Rigid throughout entire depth.

2nd. Sheet Asphalt=Plastic surface on rigid binder, both layers of approximately equal thickness.

3rd. Bituminous Coated Portland Cement Concrete=Thin plastic mat, cemented by a film of bituminous cement to a rigid base.

4th Warrenite-Bitulithic=Plastic surface blended with a rigid lower portion.

The black horizontal lines to the right of the vertical zero line are intended to indicate merely in diagrammatic form how the horizontal thrust of traffic decreases from the surface downward, and, conversely, the shaded areas to the left of the zero line, to indicate how the potential resistance of the pavement decreases from the bottom upward.



No attempt has been made to draw these to scale nor to determine actual values for the horizontal pressures at any point; the whole diagram is intended to be merely indicative of what happens.

The horizontal thrust of traffic at the surface has of course been taken as the same in all four cases; also for sake of simplicity, it is assumed that the pavement is at the same temperature throughout its entire depth. This latter condition of course never exists in a pavement at any time.

In the case of a bituminous concrete mixture sufficiently rigid to resist displacement the strains are absorbed at or very near the immediate upper surface and the resistance at all depths is equal to the pressure, hence there is no deformation.

In the case of the thick layer of sheet asphalt mixture, the horizontal pressure at the surface is greater than the resistance of the plastic mixture at that point. The horizontal pressure decreases at a regular rate at lower levels and the resistance increases at a slightly greater rate so that at some depth in the body of the mixture itself they become equal. However, in the upper part of the layer where the pressure is greater than the resistance of the mixture, deformation must take place.

In the case of the bituminous coated concrete, the horizontal pressure decreases at a regular rate within the bituminous mat, then, due to the weakness of the asphaltic cement bond with the rigid portland cement concrete, suddenly drops to a very small amount in the upper surface of the concrete. The resistance varies in inverse ratio, with the same sudden reduction at the plane of cleavage; therefore in this case the bituminous mat is not only deformed within itself, but also moves or shoves on the concrete.

In the case of Warrenite-Bitulithic, however, on account of the blending of the fine plastic mixture with the rigid coarse mixture, the fine mixture is not of uniform depth; it varies in thickness from say ⅛ in. to ¾ in. within the area of but a few inches—and is therefore anchored in place by the tops of the coarse stones of the rigid mixture below, as is plainly shown in a later series of photographs (pages 12 and 13).

Therefore at a practically negligible depth the resistance of the pavement equals the horizontal thrust and no deformation takes place.

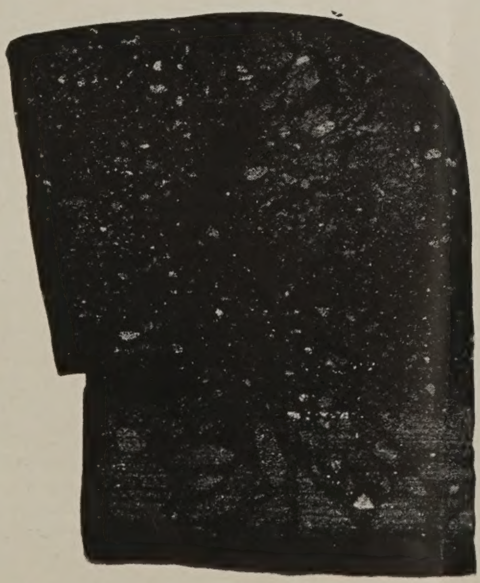
In order to demonstrate this more clearly I show here photos of an experiment recently made at our laboratory in Cambridge. The upper photo shows the apparatus. The samples were each 2 in. wide by 4 in. long. The sample at the left is composed of 1 in. standard dense binder and 2 in. of a sand mixture rich in bitumen. The sample at the right is 1 in. of the same binder with ½ in. of the same rich sand mixture; however, in this case the sand mixture was placed on the binder while it was in a malleable condition, hence a certain amount of blending has taken place.

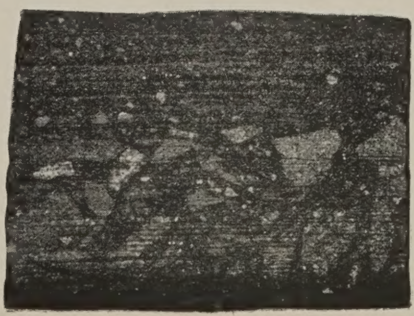
The two samples are firmly held in place by the blocks of wood shown at both sides of the binder and the strip of canvas is held in place in the center by the iron plate so that as the ends of the canvas are pulled by the two 5 lb. weights the canvas presses against the back and top of each sample with the same amount of pressure.

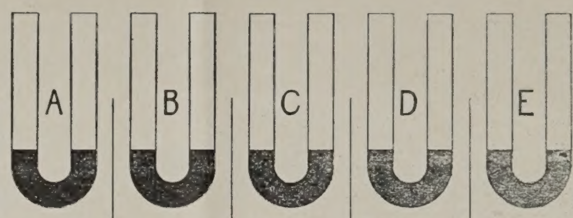
The lower pictures are actual size photographs of the samples after twenty-two (22) hours at a temperature of 70 degrees to 82 degrees F.

These show that while the 2 in. layer became distorted and finally was torn within its body, the ½ in. layer was entirely unaffected.

In making the above experiment, naturally the samples were at the same temperature throughout, however, as already mentioned, this condition never exists in a pavement in actual use. On a normal summer day the upper







SIZE OF PARTICLES.	10 MESH	50 MESH	100 MESH	GRADED 10-200	200 MESH
VOIDS	40 %	40 %	40 %	30 %	50 %
TIME REQUIRED FOR WATER TO PASS	1 MIN.	22 MIN.	89 MIN.	3 HOURS	24 + HOURS

surface is heated by the sun to a relatively high temperature, often to well over 100 degree F. and toward the end of the day the heat will have penetrated a considerable depth.

While in this condition, the upper portion of the wearing surface layer is relatively much more plastic than the lower portion, therefore its relative resistance to deformation is less than has been indicated in the diagram (page 6).

During the night, however, the upper exposed surface of the pavement radiates its heat, and by early morning may be considerably cooler and therefore in the case of a layer of uniform composition such as Bitulithic or Sheet Asphalt Surface mixture, the upper surface may be less plastic than the center of the layer, thus presenting to traffic a "tough crust" supported by a plastic mass.

The effect of traffic under such conditions may be either deformation in the body of the surface layer, or, if the difference in temperature is extreme, possibly fracture of this tough upper crust.

In the case of the Warrenite-Bitulithic, however, this difference in temperature merely makes the immediate upper surface more nearly resemble the lower portion as to rigidity and therefore as the two are blended firmly together no harm results.

Blending

An idea of the strength of the bond formed by this blending of the two mixtures can be obtained from an examination of this sample of Warrenite-Bitulithic which has been sawed horizontally into four slices, also by an examination of this series of photographs of another sample cut similarly (pages 12 and 13).

We have already seen how the Bitulithic pavement was affected by moisture after the flushcoat bitumen had been worn off by traffic, also seen that it was not so dense or compact at the surface as it was lower down; however, it remains to be shown how the surface of such a bituminous concrete mixture composed of a mineral aggregate containing much less than 21% of voids can be really sealed with a hot sand mixture composed of an aggregate containing much more than 21% of voids.

Impermeability

The answer is simply that the *permeability* of a pavement to water is *dependent far less* upon the combined total volume of all the interstitial spaces in the aggregate, or, as usually referred to, "the percentage of voids," *than it is upon the size of each individual void.*

The experiment shown on the above diagram shows this fact very conclusively.

In this experiment we used ordinary 7 in. glass U tubes of approximately ¾ in. internal diameter. The same volume of aggregate was compacted as uniformly as possible in the bottom of each tube, and as the weight of aggregate used in each varied consistently with the percentage of voids in each aggregate we feel the degree of compaction was fairly uniform in all.

Tube A—contained sand passing No. 10 retained on No. 20 mesh sieve.

Tube B—contained sand passing No. 50 retained on No. 80 mesh sieve.

Tube C—contained sand passing No. 100 retained on No. 200 mesh sieve.

Tube D—contained sand graded from No. 10 to 200 mesh sieve inclusive.

Tube E—contained dust passing No. 200 mesh sieve.

The sands in A-B-C each contained 40% voids.

The graded sand in D contained 30% voids.

The 200 mesh in E contained 50% voids.

One leg of each tube was filled with water and the time required for the water to pass through the aggregate, until the water level was the same in both legs of the tube was measured in each case.

These times were

Tube A— 10 mash sand— 1 minute.

Tube B— 50 mesh sand—22 minutes.

Tube C—100 mesh sand—89 minutes.

Tube D—Graded sand—about 3 hours.

Tube E—200 mesh dust—at the end of 24 hrs. there was still a difference of ¼ in. in level and the water had apparently stopped.

It should be noted that the percentage of voids in tubes A-B-C is the same—40%; also that the dust in Tube E contained the highest percentage of voids, yet on account of the infinitesimal size of the individual voids it was the most impermeable.

As a check on this experiment, we then placed in these percolators, equal volumes of the coarse and fine aggregates used in a Warrenite-Bitulithic pavement. The coarse aggregate contained 14%, and the fine aggregate 30% voids. The percolators were then filled with water and the time required for a given volume of water to filter through the aggregate was measured. It filtered approximately *four* (4) *times as fast through the coarse as through the fine aggregate.*

As an ocular demonstration of how the compactness or denseness of a surface depends not upon the percentage of voids but really upon the size of the individual voids, I would call your attention to this box in which there are four (4) bituminous mixtures, of ¾ in. stone, ½ in. stone, 10 mesh sand, and 50 mesh sand respectively. These blocks are identical in the following respects:

(*a*) Total volume of block = 27 cubic inches.

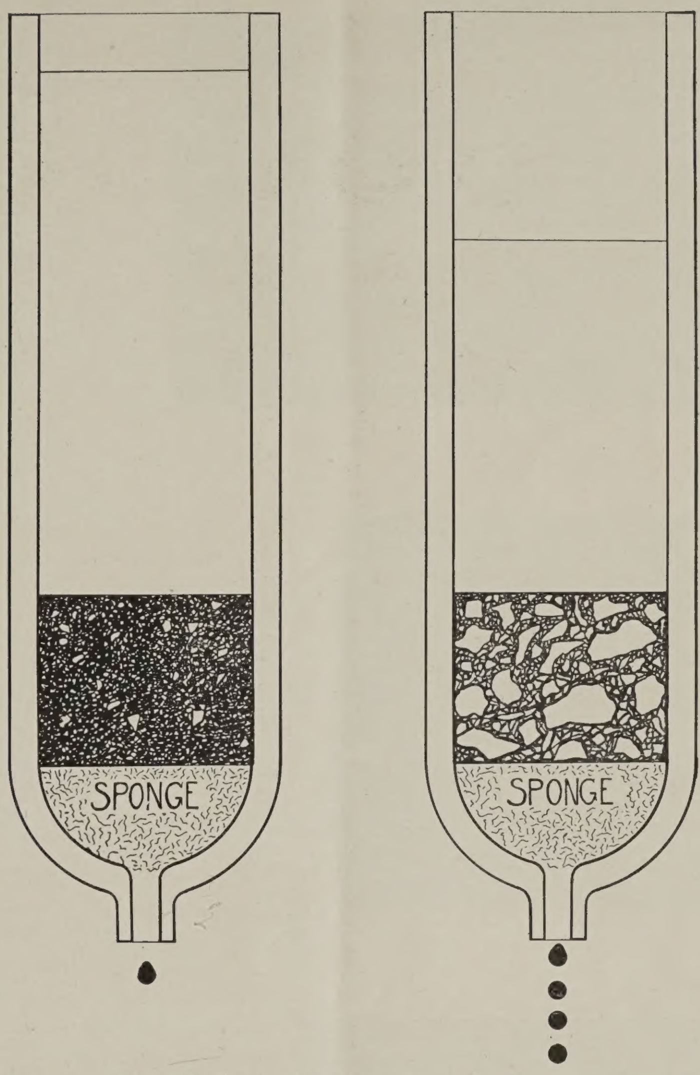
(*b*) Mineral aggregate in each consists of particles of uniform size.

(*c*) Mineral aggregate in each case contains approximately 40% of voids.

(*d*) Total volume of voids in each block equals approximately 10.8 cubic inches.

(*e*) Each block contains just sufficient asphaltic cement to coat the particles.

Therefore if the compactness or denseness of the surface depended upon the percentage of voids (total combined



volume of voids) then the denseness of these blocks should also be identical.

An examination of the surfaces of the blocks (see photos, page 10) shows plainly that the compactness of the surfaces is not identical but increases as the size of the particles used in the mineral aggregate decreases.

This is even more plainly shown by the sawed cross sections of the blocks (see photos page 11).

In these photographs the spaces between the white stones appear black due to the coating of asphaltic cement on the stones at the back of such spaces or voids.

From these photos it is clear that the 10.8 cubic inches of voids in the ¾ in. stone block are composed of relatively large sized individual voids, the structure resembling the coarse broken stone placed at bottom of a drainage ditch.

In the case of the block composed of 50 mesh sand the same 10.8 cubic inches of voids consists of an almost infinite number of microscopic individual voids, hence the texture of the surface and cross section of the block more closely resemble that of roofing slate.

Denseness of Surface

One of our laboratories recently demonstrated this denseness of a surface by the use of two sieves as shown on the diagram, page 14. The sieves were each made four (4) in. square. The one at the left was made of ½ in. bars with the openings ½ in. square. The other sieve was a standard 200 mesh sieve, in which the diameter of the wires was the same as the width of the openings. Therefore in each sieve the total area of holes was 4 square inches or 25% of the area of the screen, yet while water could be poured freely through the ½ in. sieve, the 200 mesh sieve would hold water ¾ in. deep. The reason being the tremendous difference in the size of the individual openings, the 4 sq. in. of openings being divided into only 16 holes in one case and into 640,000 holes in the other.

It is for this reason that the fine aggregate mixture at the upper portion of the Warrenite-Bitulithic makes it "densest at the top" as described in the patent.

This term "densest at the top" when applied to pavements is likely to be confused with "density", or "specific gravity."

The dictionaries define "dense" as meaning compact, close, thick, closely compacted, etc.

Denseness vs. Density

In some senses of the word "density" is synonymous with "denseness"; in another sense "density" is synonymous with "specific gravity"; but "denseness" and "specific gravity" are never synonymous. For example, one might speak of the 'denseness' or "density" of population; on the other hand the specific gravity of the population would be meaningless. Conversely while one might ask for a special "density" or "specific gravity" of motor gasoline and be understood, it is hard to tell what he would receive if he asked for that "denseness" of gasoline.

While the word "density" is not once used in the Wallace patent and the meaning of the word "densest" is perfectly clear from the context, some people have felt confused with this term "densest at the top", knowing that a coarse aggregate stone mixture containing but a small percentage of asphalt must have a greater specific gravity, or density, than that of a sand mixture containing a large percentage of asphalt.

In order to clear up any possible confusion on this point, I would ask you to examine these three (3) small blocks, which are of equal volume.

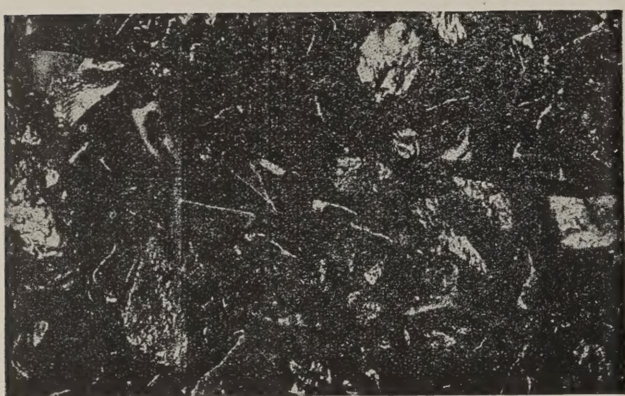
They were prepared by first determining the percentage of voids in the sand, then mixing a given weight or volume of the sand with just sufficient volume of the filling medium to fill the voids.

The filling medium in block A was paraffine wax, in

Size of Particles In Each Block

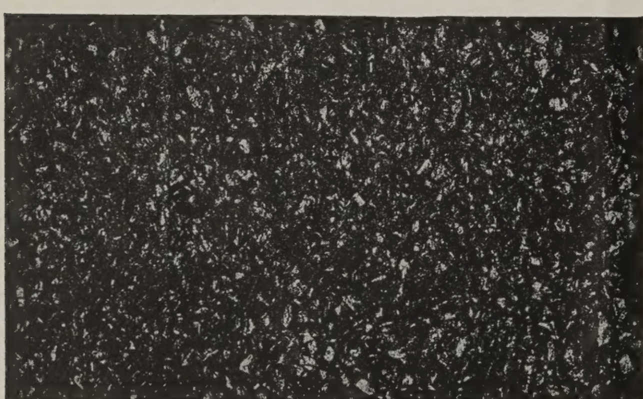
¾" Stone

Surface



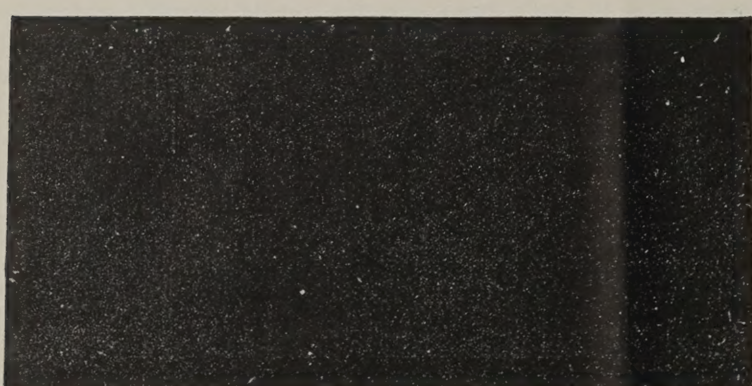
½" Stone

Surface



10 Mesh Sand

Surface



50 Mesh Sand

Surface

Size of Particles In Each Block

¾" Stone

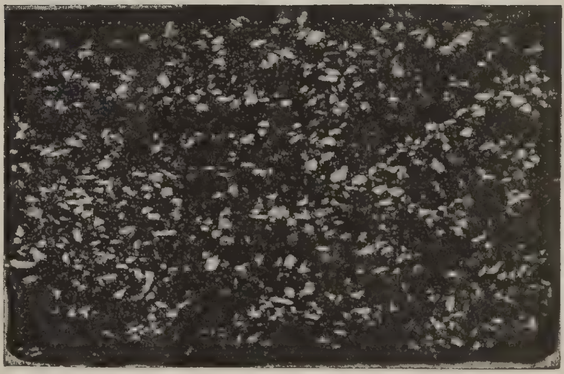
Sawed Cross Section

½" Stone

Sawed Cross Section

10 *Mesh Sand*

Sawed Cross Section

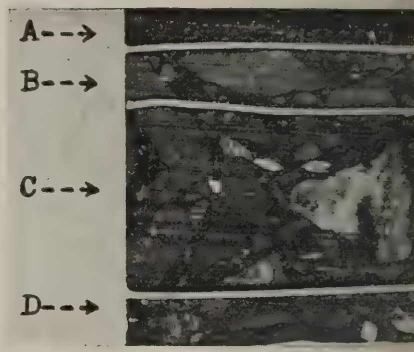


50 *Mesh Sand*

Sawed Cross Section

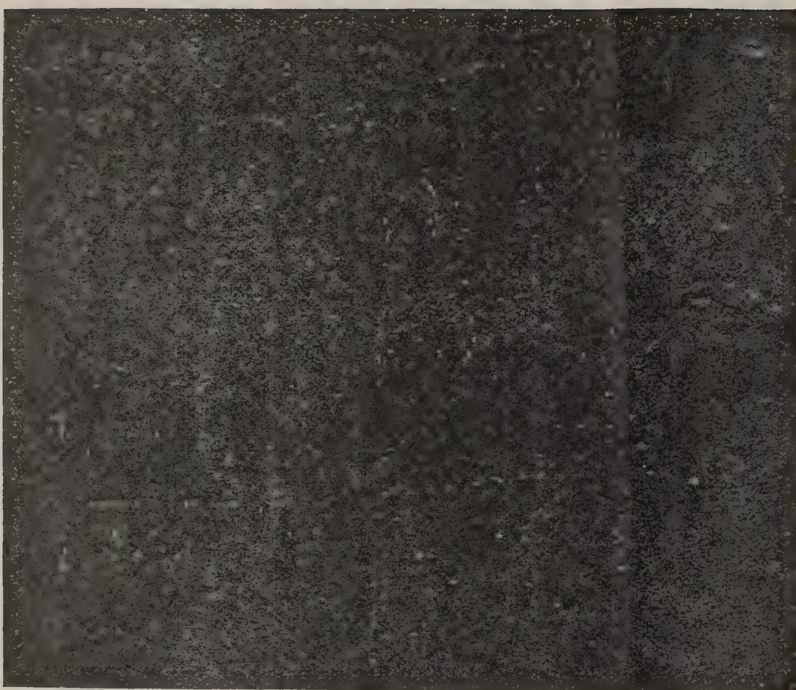
Warrenite-Bitulit

(Laid $1\frac{1}{2}''$ depth on De



Sample sawed horizontaily
into four (4)

While this sawed vertical
Mixture is blended and bonded
ture, this condition is more clea



Upper Side of Slab—"A"

This is the surface exposed to traffic

Photo shows the fine grained, compact character of the Fine Surfacing Mixture which seals the surface and protects the Coarse Mixture below.

Lower Side of Slab—"A"

$\frac{3}{16}''$ below surface exposed to traffic

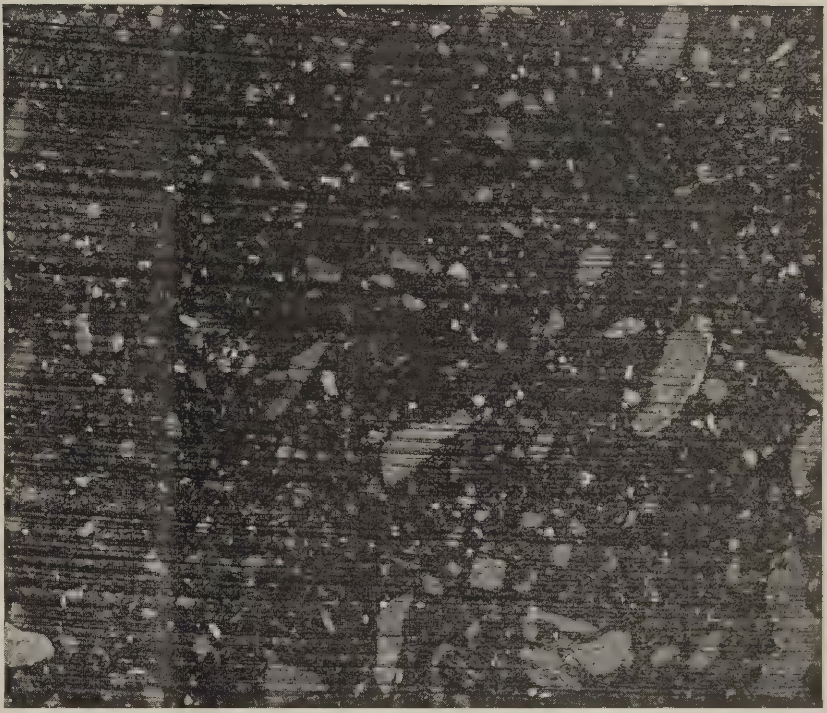
Photo shows that in the lower portion of Slab "A" the two mixtures blend. The "coarse particles" seen in the photo being in reality the tips of stones protruding upward into Slab "A" from the coarse mixture below.

Wearing Surface

Asphaltic Concrete Base)

ong white lines in photo)
s—A-B-C-D

shows how the Fine Surfacing
h the top of the Coarser Mix-
hown in the succeeding photos.

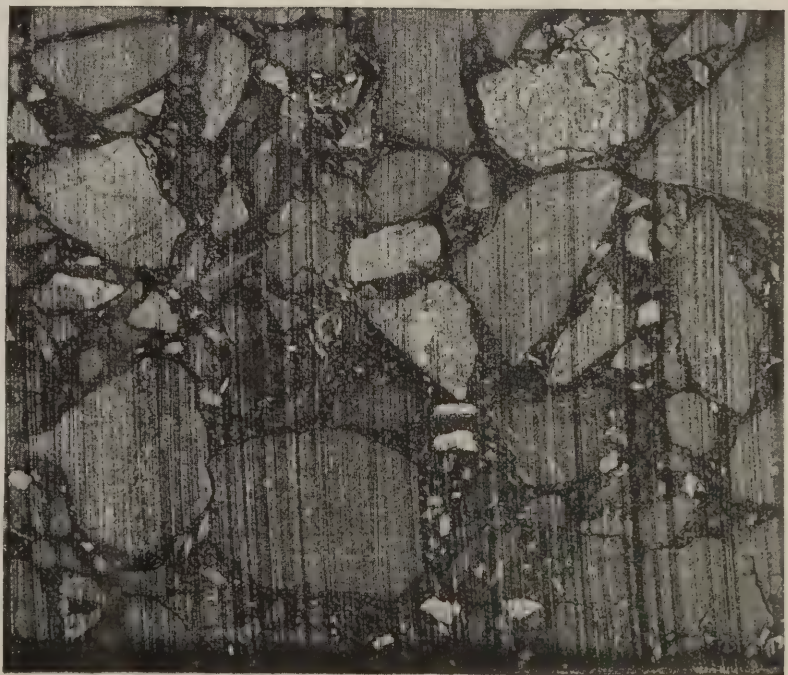


Upper Side of Slab—"B"

¼" below surface exposed to traffic

1/16" below lower side of Slab—"A"

This photo shows a further blending of the two mixtures, and when compared with Lower Side of Slab—"A" shows an increased proportion of the coarse mixture and a decreased proportion of the fine mixture.



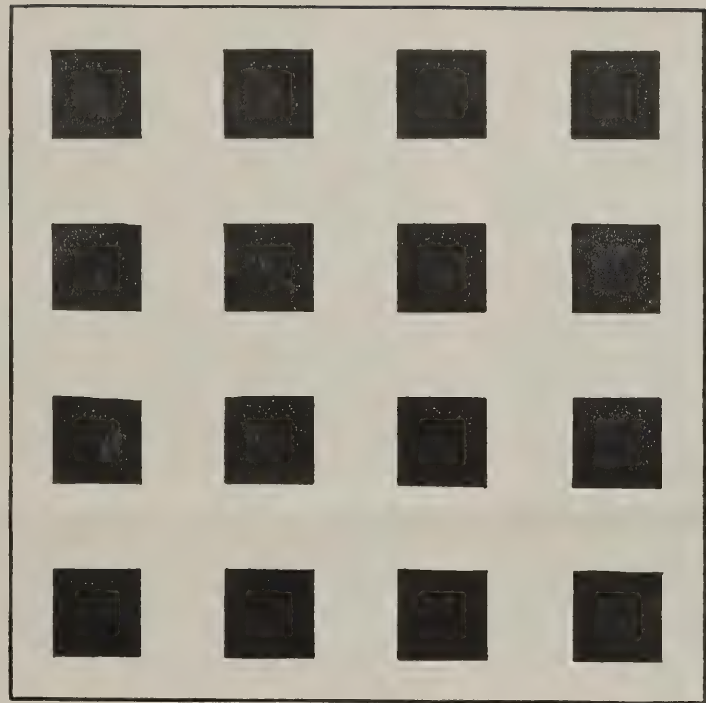
Lower Side of Slab—"B"

⅝" below surface exposed to traffic

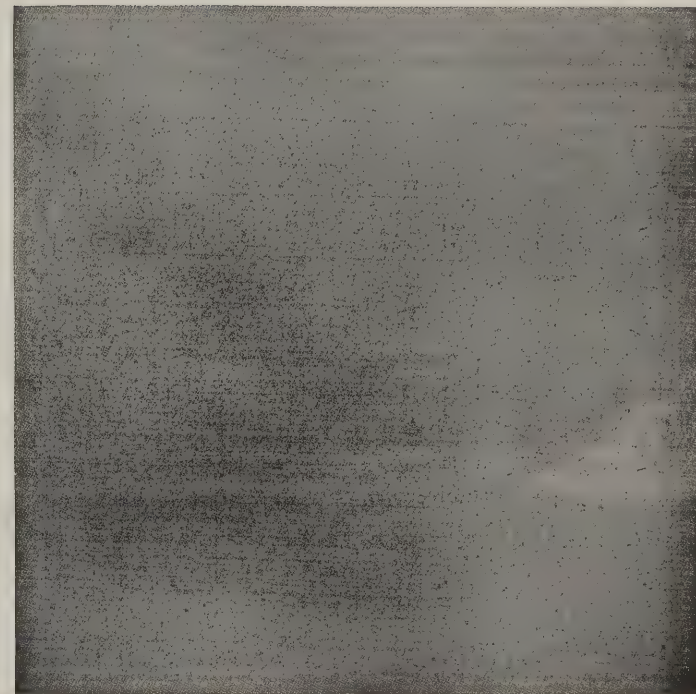
⅜" below upper side Slab—"B"

Photo shows that (in this sample) at this depth, the structure consists substantially of the coarse aggregate asphaltic concrete mixture.

(The depth at which this takes place will vary with conditions under which pavement is laid.)



½″ MESH SIEVE



No. 200 MESH SIEVE

Size of each Sieve=4″x4″
Area of each Sieve=16 square inches.
Area of holes in each Sieve=4 suare inches.
Area of holes in each Sieve=25% of area of Sieve.
Number of holes in ½″ mesh Sieve=16.
Number of holes in No. 200 Mesh Sieve= 640,000.

block B asphalt cement, in block C a mixture of litharge and glycerine.

As the *size of the voids* in each block are the same and the filling medium was just sufficient to fill the voids in each case, the blocks must be of equal *denseness,* however, no two are of the same *density.*

The density or specific gravity of the blocks are

Block A—using Paraffine— 1.96
Block B—using Asphalt Cement—2.00
Block C—using Litharge— 3.54

The specific gravity of the sand was 2.65 or more than blocks A and B and less than block C. This seems to be conclusive proof that when comparing different mixtures, specific gravity is not a measure of "denseness."

Increase in Stability

Another very important point which may not have occurred to you is that by blending this fine aggregate plastic mixture with the top of the coarse aggregate bituminous concrete, *we actually increase the stability of the rigid concrete.* This may seem paradoxical, but it is a fact.

While we all appreciate that the stability of waterbound macadam is due to the interlocking of the coarse, medium and fine sized particles of stone, yet frequently forget that this stability is not due merely to the selection of the proper proportion of each of those several sizes.

An engineer might easily compute very closely just what percentage of each size stone is required, but if he should specify that said sizes be mixed together in such proportions and then be spread in one layer, no contractor would ever be able by rolling or any other means to compact that layer into a stable macadam road.

The real secret of MacAdam's success lay in his process of laying, viz.: spreading and compacting a layer of coarse stone, then spreading there-upon a layer of finer stone and compressing these smaller particles into the space between the *tops* of the underlying coarser stones. By this method each stone was firmly seated on a solid base and what is more important, the *top point of each stone was given lateral support* by the smaller stones wedged in around its top.

The importance of this will be seen when one remembers that as the foundation remains stationary there is no tendency to displace the bottom of any stone but on the other hand the effect of moving traffic tends to overturn the stones and the only way to prevent this is to give the top of each stone lateral support.

This is exactly what is done when the fine mixture of the Warrenite-Bitulithic is forced down into the spaces between the tops of the upper stones. On the other hand, if a bituminous concrete is rolled as was done in the old Bitulithic, pushing the stones down and forcing the fine mortar up from the bottom, then the mortar between the bottom of these stones is highly compressed but the mortar between the tops of the stones is not under pressure, and merely acts as a filler.

In other words, the upper stones in this present pavement may be compared to a stiff leg derrick, but those in the older pavement to a flag pole set in a solid foundation.

We have already shown that in the practical laying of coarse aggregate bituminous concrete mixtures, it was impracticable to use aggregates containing a minimum of fine material and hence a maximum of stability on account of the fact that these aggregates were so rigid that when compressed by the roller a large percentage of the uppermost stones were crushed; also that after the flushcoat mat had worn off the traffic fractured and even shattered a still greater number of these exposed stones, hence it was necessary to use a compromise design in which an excess of fine aggregate was added to the mixture so as to cushion the stones in the body of the mixture under traffic. This, however, did not protect the uppermost stones and did reduce the stability of the aggregate to a material extent.

These two weaknesses are overcome by the use of the fine aggregate mixture at the surface in accordance with present methods, because this acts as a cushion for the roller at time of construction, also protects the upper stones from the abrasion and impact of traffic. For these reasons, *when using this method of construction it is possible to use a more stable and rigid aggregate for the lower coarse mixture* than could be possibly used under the old methods of compressing the bituminous concrete and then temporarily sealing the surface with flushcoat bitumen.

In conclusion we may summarize "The Advantages Secured by Sealing a Bituminous Concrete Pavement with a Hot Sand Mixture" or in other words, the advantages of the Warrenite-Bitulithic pavement laid under the Wallace patents as follows:

(a) It can be laid on any suitable foundation.

(b) It will not crack like a rigid pavement such as portland cement concrete.

(c) It can be laid quickly on macadam or bituminous concrete base, thus avoiding barricading the road and requiring detours for long periods during construction.

(d) It has all the merits of the macadam road, the sheet asphalt pavement, and of the best coarse aggregate bituminous concrete.

(e) It has overcome all the weaknesses inherent in each of these structures.

(f) It is not merely a bituminous concrete with a temporary sealcoat mixture, but is really a *distinct product radically different in composition, structure, physical characteristics and wearing qualities from any pavement hitherto constructed.*

Discussion of Mr. Perkins' Paper

By Julius Adler
Deputy Chief, Bureau of Highways, Philadelphia, Pa.

For the purpose of discussion, the paper just presented may be considered under two headings:—

I. The merits of the mixed seal coat as compared to the flush seal coat;

II. The merits of the particular method of construction described, and of the resulting pavement structure.

I. Under the first heading, are included the following:—

(*a*) Greater and more permanent water-proofness than the old flush seal coat;

(*b*) Cushioning effect during rolling, permitting the use of the most desirable grading of coarse aggregate;

(*c*) Cushioning effect under traffic, protecting the coarse aggregate from the direct impact and abrasion of traffic.

Those who have had experience with the older form of asphaltic concrete construction, and who have taken pains to observe their behavior in service may be disposed to dispute some of these claims of superiority by citing examples of the old pavements which have given very satisfactory results. Viewed from the standpoint, however, of the average results obtained from a considerable number of examples of pavements, it should be conceded that the mixed seal coat has the qualities claimed and that one of the older pavements, which has performed well without the assistance of hot mix seal coat, should have done even better had this feature been included in the original construction.

II. As to the merits of the method of construction described and the resulting pavement structure, we have been told that the present form of Warrenite-Bitulithic is fundamentally different from any other type of bituminous pavement which has preceded it, possessing a very desirable degree of uniformity of compression from top to bottom; and, further, differing from sheet asphalt in that the latter contains a well defined cleavage plane between the upper and lower courses as contrasted with the Warrenite type where the fine mixture is said to blend with the coarse mixture through a depth varying from ¼ to ¾ inches from the surface of the pavement.

While there can be no doubt that a difference exists in this respect between the two pavements, since the coarse mixture in the sheet asphalt has been rolled to a nearly uniform surface prior to spreading the fine mixture, there is room to question whether the resulting condition can properly be described as a cleavage plane. To the contrary, if the binder course is properly designed and laid, a very satisfactory mechanical bond (in addition to the adhesive bond, which alone has been attributed to this type of construction) can be obtained.

With respect to the single compression process used on the W. B. pavement, there can be no doubt of the very effective combination of the fine and coarse mixtures which results. It may be of interest, however, to know that as early as 1914, in the City of Philadelphia, a hot mix sand-seal coat was used on bituminous concrete of coarse grading, on which work the seal coat was spread immediately after the bottom course had been lightly rolled to an even surface. A number of stretches of this pavement were laid in 1915, practically all of the work being done under favorable warm weather conditions and these pavements have given very satisfactory results. Had the weather been cold at the time this work was done, it is very questionable whether as good results would have been obtained. It must be borne in mind, however, that when any bituminous mixture is spread in a thin coating in cold weather, there is a possibility of a rapid chilling and subsequent surface scaling unless rolled almost immediately after the spreading.

The next point for consideration in the matter of structure of the pavement under discussion has to do with the thickness of the seal coat. It would appear that this form of construction is based partially upon the principle that an upper plastic mixture is desirable only in sufficient quantity to give a proper combination of water-proofing and cushioning. In the case of the W. B. pavement, this has been set apparently at an average of ½ inch of fine graded mixture. In the case of the old sheet asphalt pavement, the upper mixture was usually 2 inches. Experience has proven beyond any doubt that the latter depth is too great under modern heavy traffic and very difficult to keep from waving. The result is that the modern heavy traffic asphalt pavement usually has a 1½-inch surface course. From the standpoint of water-proofing, this is undoubtedly thicker than necessary, and from the standpoint of cushioning it also seems very probable that it is greater than necessary. It has been found possible, however, with a well graded binder mixture and under reasonably favorable weather conditions to lay surface mixtures as thin as 1 inch. With poorly graded binder course, and working in cold, windy weather, a mixture as thin as this is likely to develop waviness and excessive honeycombing, due no doubt, to the rapid and unequal chilling beginning at the surface. Assuming, however, that such a combination can ordinarily be made, the fundamental difference between the two pavements is reduced to that between a 1-inch surface of fine mixture rolled in a separate operation, and a ½ inch similar surface combined with the lower course in a single operation. The apparently undetermined questions are, first, whether a ½-inch mixture is ample to give proper cushioning effect under all variations of traffic from light to heavy; and, second, whether in the event that a thicker surface mixture would be desirable under heavy traffic, the anchoring effect of the more rigid binder course which has been so clearly brought out by Mr. Perkins in his discussion of the variation in stresses and resistance to stresses at varying depths in asphalt pavements is sufficient to retain in place and free from waving, a coating as great as 1 inch in thickness of what has been described as an essentially plastic mixture.

The Proper Methods to Follow in the Control of Paving Mixtures

By H. S. Mattimore
Engineer of Tests, Pennsylvania State Highway Department

As used in the title of this talk, the term control is a very broad one, as in my mind when we mention the control of paving mixtures we would naturally include all supervision by the Municipality or State covering materials, and the actual placing of the pavement. There is further control or supervision which is left entirely in the hands of the contractor. Although this latter will not be discussed, it must be remembered that the cooperation of both interested parties is necessary in order to obtain desirable results.

It is always difficult to lay down any line of procedure and definitely label it as the proper method; in fact, I doubt if the same system adopted in any municipality or state can necessarily be considered the ideal one for another state or municipality to follow. The procedure will be effected in any section by the organization, the experience of the engineers and inspectors in this organization, and finally by the efficiency of the various bureaus in which the organization is divided. There are certain systems of control with which I am familiar, and under which successful work has been accomplished, and I have assumed that naturally this is the line along which the treatment of this subject would be most valuable.

I would interpret that control of paving mixtures, as used in the title of this talk, would treat of the determination of qualities for the various materials entering into the mixture and the supervision of the placing. All materials entering into any paving mixture should be tested, and naturally, as the laboratory has skilled men and equipment for this purpose, this should be under their supervision. Also, mixtures should be designed, that is, whether a pavement is laid of concrete or of bituminous material, we must have a predetermined mix to be used in proportioning the different ingredients. This mix is determined usually as a result of laboratory tests combined with service test. The intelligent way to determine the mixture to be used should be by cooperation between the field and laboratory forces. The laboratory should be familiar with the theoretic data concerning mixtures of this type, and also have data on the behavior of such type when subjected to traffic. The construction engineer should be able to give advice regarding past experiences in the use of various mixes from the standpoint of economical manipulation and finally the efficiency of service. This latter will include maintenance costs, etc.

The mixture as determined before hand as one to be approximated for specifications and bidding purposes, will in many cases be subjected to change to fit available aggregates, and such changes should be entirely under the control of the laboratory. These changes of mix occur more frequently in the bituminous types than in the concrete, as in the former, the difference in grading of the available materials has more effect on other ingredients than in the latter. Also, the mixtures of bituminous pavements depend on traffic and temperature conditions, while the usual practice in concrete pavement is to standardize one mix within large sub-divisions such as municipality or state.

The control of bituminous paving mixtures during construction is connected very intimately with determination tests. For instance, in the wearing surface of a sheet asphalt pavement, asphalt, sand and filler are mixed in certain proportions. In order to control this intelligently, daily samples should be submitted to the laboratory to determine if these proportions are being obtained in the actual mixture. Naturally this work must be closely supervised by the laboratory. Under our scheme of organization the inspector on bituminous plants is assigned from the construction forces, but he is trained and his work is supervised by inspectors from the laboratory. We have found that efficient control can be maintained in this manner and results on tests are available to the plant inspector within forty-eight hours at a maximum.

The status of the laboratory in the laying of bituminous pavements will depend to a large extent on the general experience of the field organization in that type of pavement. Trained construction engineers with a large amount of experience with this type are fully capable of taking full control. In cases where the construction engineer has a limited experience with this type of pavement he should have expert advice regarding placing temperature, proper raking, rolling, and methods for avoiding or repairing honey combing, etc. The ultimate end in this instruction is to make the inspector self-contained so far as the laying and manipulation of this type of pavement is concerned.

The control of concrete pavements, in the main, should be directly under the construction engineer. Such factors as proportioning of mix and time of mix should be regulated by specifications. As these depend to some extent on test data, naturally the laboratory is consulted regarding them. Consistency is controlled by the inspector after proper instructions. The determination of the quality of the mix by means of test specimens, naturally, is a laboratory function. It is quite practicable to train construction inspectors in the making of specimens, and to my mind this is a desirable procedure, as the inspector becomes thereby, intensely interested in the quality that he is securing, which has a tendency to increase his efficiency.

I do not wish to be misunderstood in the above discussion regarding control of paving mixtures. It might seem as though we are working under a dual authority, which is far from the actual conditions. In fact, under our scheme of organization, the district engineer is in charge of all construction and maintenance within his district, which is usually from four to seven counties, depending upon the amount of construction. He is responsible for the quality of all the construction under his authority, and in order to assume this responsibility he must have full supervision. On certain types of pavement such as many of a bituminous class, the quality of the work secured is regulated to a large extent by the proper grading and proportioning of several ingredients. The ascertaining of this quality depends on tests. The district engineer naturally has no facilities to carry out this work, and such details are left to the laboratory. In cases of orders being issued to the contractor of a major nature, great pains are taken to see that such are taken through the district engineer; in fact, in all types of pavement the laboratory acts in the supervising capacity to the district engineer, and he feels sure that he will receive prompt advice on any questions regarding paving mixtures. This naturally leads to an excellent cooperation. There are absolutely no signs of dual authority, and excellent progress and qualities are the result.

The inspection and methods for the control of the quality of materials entering into any paving mixture is a large factor in determining the final quality of the pavement. The actual testing of materials has been well controlled for a number of years. Efficient methods for the testing of highway materials are used extensively, and although many of them have not been standardized, they are well known and followed in highway laboratories.

The weak feature regarding materials in the past, has been the want of control on the materials actually being used in the mix. This was not peculiar to highway work, in fact, it was a general condition found throughout all construction. Within the past several years attempts have been made to correct this weakness, and many highway organizations have made provisions to carry on this work, and it has been found that it is not only an excellent safeguard, but also an economic procedure.

At the present day when we are studying the design of pavements and recognizing the effect that the quality of the material has on the ultimate result, no thinking engineer would question the necessity for the control of mater-

ials. The phase of this subject that is of most interest would be the organization and methods of this control. It is questionable just how much could be done towards standardization of an organization for this purpose. Many conditions peculiar to different highway organizations would have their effect on the method to be followed.

There are two distinct methods followed in organizing for this material control; in one the laboratory or testing bureau has full control of all materials and has proceeded to the stage where a material inspector is assigned to each contract. The other extreme is where the laboratory tests the materials only, and the control is maintained through the constructions corps. The method followed in our organization might be considered a mean, in that, the supervision of all materials is under control of the laboratory; but in cases of field inspection on a contract, the work is actually done by the construction inspector. During the early stages of organization, great pains were taken to instruct this inspector in methods of field testing for various materials, and as he is able to give this material work the proper attention along with his inspection of construction, it will be readily seen that it is an economic procedure; and further as the inspector of construction is responsible for the finished results, he takes great pains in the testing of materials, the quality of which he knows is a great factor in determining these results.

Another question which often arises in regard to inspecting and field testing of materials, is whether this should be carried on at the source of production or upon delivery. I realize in discussing this phase of material control that very definite views have been stated regarding both methods. I consider that where at all practicable, that cement and brick should be tested and inspected at the source of production, also where any considerable amount of steel is used for structural work it is advisable to have such tests and inspections at the plant, in fact, it is the only way to control this latter. For fine and coarse aggregate, I have found during past experience, that it is a practicable procedure to make this inspection and field test upon delivery at the contract. I realize that this procedure is not agreeable to all producers, in that they seek to know whether this material will be acceptable before it leaves the plant, but I do know that skilled producers make it a business to be familiar with the specifications and assure themselves that it does meet these specifications before it leaves their plant, and they do not need an inspector from the state or municipality to guide them on this.

The only place I consider where an organization is justified in maintaining an inspector at the source of supply of fine and coarse aggregate is at very large plants where the shipments are sufficient to warrant this from the standpoint of expense, and what is of greater importance, furnishing a real occupation for the inspector. Where the amount of materials is only a few cars a day, the inspector is seldom busy, and as a result it is far from being a desirable occupation for an ambitious man. Under this method where there is sure to be a large turnover of inspectors, it is very apt to lead to inefficiency, also it has been observed that material coming from such plants is not of any better quality than that coming from plants where the responsibility is placed on the producer.

Occasionally we hear discussions regarding the proper grading of coarse and fine aggregate. I have been informed by construction engineers that in many locations it is practically impossible to secure a grading in accordance with specification requirements. To my mind this is rather a weak assertion by any construction engineer. If this grading is required by the specifications, and he has proper respect for these specifications, he should make it a point to see that this grading is secured. For instance, in coarse aggregate the concrete grading which is standardized for this district calls for material passing the 2¾ inch screen, and rejected on the ⅝ inch screen, a tolerance is given in this latter screen of fifteen per cent passing; now this grading can be secured, but I might say that it will not allow a producer to rob various sizes in order to furnish a desirable price market. If I was the contractor I would pay particular attention to this phase of material qualities. A one sized stone requires more cement in concrete, and when certain graded stone was specified this was taken into account, therefore, an engineer who allows the use of one sized stone is abusing the contractor, and the latter should object to it. If the two interested parties insist on the right grading, it certainly can be secured.

Although constant inspection is not considered advisable or economical at all plants producing coarse and fine aggregate, I consider that periodic inspection should be made at these plants by men skilled in the preparation of material, so as to furnish advice and assist the producer. This method of cooperation keeps the producer informed regarding qualities, and the inspector, during such visits, should be able to suggest methods to rectify defects in quality which have been reported from the field.

Discussion of Mr. Mattimore's Paper

By R. B. Gage
Chemical Engineer, New Jersey State Highway Department

The writer would like to further emphasize many of the points brought out in Mr. Mattimore's paper. It is very evident that if the maximum amount of benefit is to be secured from the work being performed, regardless of the type of construction or methods used, there must be close cooperation between the field, engineer, and laboratory forces. Each has its specific duties to perform and each should welcome all the assistance it can secure. If the members of one division are indifferent or jealous of those in another division, it is self-evident the cooperation necessary to secure the best results will not be secured. If engineering or methods of construction are defective or not properly performed, the quality of work is sure to be inferior to what would otherwise be secured, regardless of the character of the materials used; while on the other hand, when inferior grades of materials are permitted to be used, it is seldom the engineering or construction methods are so changed as to overcome the handicap thus caused, and again, we will find an inferior grade of work.

In certain localities specifications are so prepared that the acception or rejection of work is based upon the character of the finished product, or in other words, the contractor can use any materials, or method of construction he desires, provided he can produce a product that will have the characteristics defined by the specifications. When the finished product fails to comply with these requirements, the contractor is compelled to replace all such work with a product that will comply with the specification's requirements. If such a procedure was followed in New Jersey, the writer does not hesitate to state that most of our contractors would have been put into bankruptcy long ago.

There is no doubt but that the Highway Department is in a much better position to locate the deposits of raw materials and determine the character of all materials used in Highway construction at a much smaller cost than can be done by the individual contractor, also, that it is to the best interest of all concerned to prevent the use of inferior grades of material or methods of construction, for the chief object in the construction of roads is to provide durable and desirable types of pavements for the use of the public at as early a date as possible. The public detests detours, and is only indirectly interested in any quarrels between the contractors and the Highway Department; consequently, the rejection of a completed pavement only delays the opening of the road to travel, and increases the cost of the work to the contractor. Since most of the moneys received by contractors doing Highway work comes from the same source, it means, that the State has to eventually pay for all work that has to be replaced by the contractor. It is thus quite evident that the most economical and satisfactory method to follow is to prohibit the use of inferior grades of materials and methods of construction to such an extent that inferior grades of work will be eliminated.

The policy of the New Jersey State Highway Laboratory has been along these lines, and the speaker feels quite positive that contractors who have made a serious effort to comply with the requirements of their contract have had very little trouble with the laboratory forces. To properly carry out such a policy it is necessary to keep a very close supervision, not only of the materials being used, but also the manner in which these materials are incorporated into the pavement. Since the quality of the pavement depends upon the use of these materials in definite quantities, and the determination of these quantities is usually a laboratory process, it naturally follows that the control of the quantities required of these materials is just as much a laboratory function as is the determination of their quality.

In most localities the determination of the quantity of the different ingredients to be used in the preparation of a bituminous pavement is left entirely in the hands of the laboratory forces. This method of procedure has, no doubt, given the best results, otherwise it would not be so generally used. In some localities the same procedure is also followed in the preparation of Portland Cement Concrete pavements; that is, the proportion of the materials being used, and the methods followed in incorporating these materials into pavements are placed under the jurisdiction of the laboratory forces. This method should be universally adopted, for there is no doubt, in the speaker's opinion, that the preparation of this type of pavement should be under just as strict a laboratory control as the preparation of the bituminous types of pavement. The benefits that would thus be secured may not, however, be as great as has been the case with bituminous pavements, yet the quality of a concrete pavement, when so constructed, certainly would be superior to what is now generally being constructed.

To successfully use this method of inspection with a concrete pavement, the construction inspectors should be given such a course of training, both in the laboratory and in the field that will enable them to quickly determine the general character of the paving materials being used, and paving mixtures prepared therefrom. They should also have had sufficient field experience in the construction of this type of pavement to know how the paving mixtures should be handled and incorporated into the pavement to secure the best results. Such men ought to have had sufficient technical education, that, with a reasonable amount of training, they will be able to make all the tests required, read drawings, set stakes, etc., and to so use the information thus acquired that they will know when the pavement is being constructed in the manner required. In addition, they must be honest, ambitious, and possess an average amount of common sense. These latter requirements cannot be secured in college or in the field, yet they are very essential. It is safe to assume that those who do not have these natural qualifications will seldom make good inspectors, regardless of their education, training, or salary paid.

Since 90% of the actual construction of a pavement is under the supervision of the construction inspector, it is very important that this man should be qualified along the lines above designated, however, it is also very evident that a man who has had such a technical education and practical training cannot be secured at the salary usually paid inspectors. It is certainly false economy to assume that money is being saved by hiring a cheap inspector, for a single error in the construction of a pavement that is costing forty thousand dollars ($40,000.00) per mile may decrease the life of the pavement 50%, or in other words, by such an error, which an incompetent inspector will not detect or correct, may cost the State twenty thousand dollars ($20,000.00) per mile of pavement constructed. The amount thus lost on a single contract will pay the salaries of several well qualified inspectors for a number of years.

General Discussion of Mr. Mattimore's Paper

COL. WHITTEMORE: I presume, in reference to the quality of materials, although it was not brought out particularly, that you have distinctly in mind that the quality of materials to be used in these various structures is not necessarily of the very best quality, but the best quality that is commercially available for the particular sort of undertaking. We do know there are certain kinds of sands very superior. It may be that it is like metals, as steel, for instance. In designing structures of this type, the speaker has had considerable experience, and can recall one undertaking where 30,000 tons of steel were used. Of course, they could have used a material that would have given higher results with smaller tonnage, but the cost would have been a great deal more than if using a different material not quite so strong. It is better to use the material commercially suited best to the undertaking, and I take it that the intention of these testing Laboratories is to determine of the material available, the proper proportions to give the desired results.

MR. MATTIMORE: Our aim, in the study of materials, is to utilize the most economical sources—these are selected after qualities have been determined, in that, we are seeking economy, not only in first costs, but in maintenance expenditure. Material testing and the interpretation of the same has approached the practical stage of seeking the most available supplies.

COL. WHITTEMORE: I think such work in road construction, if it is handled by an intelligent corps of engineers, analysists and inspectors, will be to the advantage of the taxpayers and the commonwealth.

MR. MATTIMORE: With respect to local materials; sand, procured locally, must be of the same quality as commercially produced sand. In stone, we would allow a small difference, but to date we never had to make this allowance.

MR. SPARKS: I would like to inquire if Pennsylvania has ever made any tests with a core drill or experimental tests where a central mixing plant has been used.

MR. MATTIMORE: No. We never used a central mixing plant in the State. We do not consider that this process is at the stage where we could safely use it, due to a tendency toward segregation.

MR. MATTIMORE: Relative tests of gravel and broken stone have been made. Frankly, I do not consider gravel as good as stone for use in concrete. In qualifying that, I do not say that I would not approve the use of gravel under certain conditions. Some states, if they could not use gravel, could not build highways, but we have found from all our tests, following up surface-wear tests in New York State for five years, that gravel was not as good as a good quality of stone.

COL. WHITTEMORE: I might cite a personal experience some years ago. We did not find as satisfactory results with the use of gravel as compared with the use of trap rock or broken stone for pavements 6 in. thick. I have no doubt that gravel can be used to make a good concrete pavement, commercially speaking, where it would be almost prohibitive to get satisfactory broken stone, but I do say that the mixture has to be different than it would be if good angular stone were available.

MR. GAGE: New Jersey appears to be quite fortunate in being well supplied with both stone and gravel in undeveloped and developed deposits. Naturally, it is a very live question whether gravel or stone should be used, since one can be produced at considerably less cost than the other. It is also to be expected that laboratory tests which favor one or the other of these materials will be severely criticised by the producers of the other. In this connection, I would like to state that there appears to be a tendency especially with Contractors and Engineers, to want laboratory methods and tests performed to a degree of fineness to about 99.9%, yet, when it comes to construction methods or products being produced, it is not uncommon to find a variation of 50% from requirements. To reduce laboratory tests to such a point of fineness when methods of construction are so loose is neither desirable or economical. If the construction and producing methods were kept within very narrow limits, it might be that some of the materials now being used would be eliminated, but until such changes have been made, there is certainly no economy in using 100% material with a 50% method of construction.

If the materials to be used are to be determined by laboratory tests or services rendered by such material, then there appears to be no real reason why gravel should not be used in concrete pavements. One of the best concrete gravel pavements in the eastern part of the United States, which happens to be situated in this State, was built from ¾ in. gravel; i. e., practically all of it would pass a 1¼ in. screen. Specimens taken from this pavement show it has a crushing strength on the average of over 4,500 pounds per square inch. To date, it is about seven years old and has given excellent service so far. Personally, I do not know of any single stone concrete pavement in New Jersey that has given any better service. No defects have developed in six years and it has not worn one-quarter of an inch during this period. It would be foolish to reject materials of the kind used in this pavement in view of the results secured both by laboratory tests and actual service in the field. It might be, if the methods of construction were so refined that they were practically 99% perfect, a pavement constructed from stone would give superior results to one constructed from gravel, but to date the writer does not believe that anything can be gained by the rejection of materials that are 75% to 90% good when our methods of construction are not over 50% perfect.

COL. WHITTEMORE: We all know that you can take a satisfactory quality of cement, sand, and stone, and one man will make a good road, and another man will make one that is worthless, out of the same materials. There is no question about that.

MR. NEWMARK: In using local stone, is there not a tendency on the part of the Contractor to try and use all sizes turned out on concrete jobs? It is my experience that there seems to be a tendency among Contractors to try and use all the stone produced. That would seem to be one of the disadvantages in the use of local stone. Should there be any wider latitude in sizes allowed in such cases, in Mr. Mattimore's opinion?

MR. MATTIMORE: No. The grading of aggregates is part of the design and the same respect should be shown for this as any other part of the specifications. The entire product of a crusher should not be used in concrete. A large proportion of commercial crushers have a waste, and the same conditions should be recognized in local crushers.

MR. NEWMARK: In ordering stone from commercial quarries the Inspector can more easily insist that the proper sizes be ordered and shipped. It costs the Contractor nothing. It is harder for the Inspector, however, to keep after the Contractor using local stone, to keep him from using unapproved sizes of stone. That I claim to be the disadvantage.

MR. MATTIMORE: Commercial stone producers calculate their waste in producing special graded products and include such in the costs. Experienced contractors working local supplies follow the same procedure. Therefore, when the inspector insists on grading to meet his specifications, he is only asking a contractor to fulfill a clause of his contract, and one that must have been estimated.

MR. KEASBEY: Do the results of strength tests of cores taken by the core drill show any distinction between the use of gravel and trap rock? Was there shown any appreciable difference in the results of the strength?

MR. GAGE: The variations between different jobs show on the average, I believe, that gravel has the best of it. I would not want to make any reflection on the use of either gravel or stone, for it so happens that gravel in one part of the States, especially in local contracts, has been more used than in localities where there is plenty of stone.

MR. MATTIMORE: It occurs to me that we are over-

estimating the value of compression strength. Compression strength has a relative value in ascertaining quality in concrete, but I have been unable to find any direct relation between compression strength and wear resistant value in concrete made of different aggregate. The concrete with the highest compression strength is not necessarily one that presents the greatest resistance to wear or traffic stresses. Concrete on one job may give a compression strength of 1000 pounds above another, and from a standpoint of wear resistance may not be any more efficient.

MR. BRALY: What have your tests shown of the difference between stone and gravel regarding abrasion?

MR. MATTIMORE: It is more of a surface impact. This starts as a rupture of the surface, then abrasion starts. Actual abrasion with rubber tires is very slight except where chains are used. Gravel has a tendency to spall out under impact more than the stone, and the smaller gravel more than the larger sizes.

COL. WHITTEMORE: I have noticed roads subjected to heavy steel tired wagon traffic. It makes a difference whether the traffic is on steel tires or rubber tires. I have seen carts drawn by six or eight horses and having four steel tired wheels, and the destructive effect of the steel tires was readily apparent very much more on the gravel concrete than on the hard trap rock, broken stone or concrete.

MR. MATTIMORE: Slag companies are trying to improve their product, and have a real desire to do so. If you understand the manufacture of slag you will realize that most of it is quite variable. We get slag from the grade that will float on water to that with a specific gravity of crushed rock. The lighter particles float to the top in a concrete road surface during finishing which accounts for the pitted surface often observed in slag concrete roads.

COL. WHITTEMORE: In Sussex County from the Canal Culvert at Ledgewood to Landing, at Lake Hopatcong, Morris County built a concrete road, and I believe it is slag concrete, at least I have been told so. (Mr. Gage interrupted at this point to inform the Colonel that it *is* slag concrete.) One notices that it does not have the smooth, even surface that is noticed with stone concrete.

Contract News

Prepared to October 24, 1922

Jan. 11—Route No. 6, Section 8, Pearl St., Bridgeton, Reinforced Concrete paving job, 0.455 miles, 20 and 30 feet wide with gravel shoulders was awarded to the Tri-State Construction Company, Bridgeton, N. J., on their low bid of $76,302.36.

Feb. 8—Route 6, Section 5, Shirley-Oldman's Creek, Reinforced Concrete Paving job, 6.812 miles, 20 feet wide with gravel shoulders, was awarded to the Benjamin Foster Company, Philadelphia, Pennsylvania, on their low bid of $254,021.53.

Feb. 16—Route 6, Section 6, Oldman's Creek-Mullica Hill, Reinforced Concrete Paving job, 5.028 miles, 20-30 feet wide with gravel shoulders, was awarded to the firm of M. Staub, Swedesboro, New Jersey, on his low bid of $203,660.48.

Feb. 24—Route 14, Section 5, Cape May Court House to Swainton, Reinforced Concrete paving job, 2.987 miles, 20 feet wide with gravel shoulders, was awarded to the firm of Sutton and Corson, Ocean City, New Jersey, on their low bid of $118,776.16.

Mar. 8—Route 6, Section 10, Quinton to Marlboro, Grading and Graveling job, 5.994 miles, 20 feet wide, with earth shoulders, was awarded to the Masterson Construction Corporation, New York City, on their low bid of $79,793.17.

Mar. 8—Route 6, Section 11, Salem to Quinton, Reinforced Concrete paving job, 2.648 miles, 20 feet wide with gravel shoulders was awarded to Joseph F. Burke, of Plainfield, New Jersey, on his low bid of $111,833.79.

Mar. 8—Route 4, Section 9, Smithville-Mullica River, Warrenite Bitulithic job, on concrete base, 3.748 miles, thirty feet wide, with gravel shoulders was awarded to C. H. Earle of Hackensack, New Jersey, on his low bid of $374,533.77.

Mar. 8—Route 10, Section 1-B, Arcadian Way to Anderson Ave. in Fort Lee, Reinforced concrete paving job, 0.48 miles, 20 and 30 feet wide with earth shoulders, was awarded to the firm of John J. McGarry, Edgewater, New Jersey, on his low bid of $104,362.61.

Mar. 15—Route 11, Section 1, Main Street, Passaic, Sheet Asphalt job, on Concrete Base, 0.257 miles, 22 feet, 2 inches wide, was awarded to Union Building Construction Company, Passaic, New Jersey, on their low bid of $15,160.15.

Mar. 23—Route 4, Section 6, Eatontown-West Long Branch, Sheet Asphalt job on Concrete Base, 2.69 miles, 20 feet wide with earth shoulders was awarded to the Utility Construction Company of New Brunswick, New Jersey, on their low bid of $149,679.74.

Apr. 4—Route 2, Section 3, South Broad Street Storm Drain job was awarded to A. G. Thompson, of Trenton, New Jersey, on his low bid of $17,665.06.

Apr. 4—Route 2, Section 3, South Broad Street, Sheet Asphalt job, on Concrete Base, 0.648 miles, 48.5 feet wide, was awarded to J. J. Barrett, Trenton, New Jersey, on his low bid of $69,433.77.

Apr. 12—Route 6, Section 9, Salem-Collier's Run, Reinforced Concrete Paving job, 4.752 miles, 20 feet wide with gravel shoulders was awarded to Sampson & Reuter, Elizabeth, New Jersey, on their low bid of $196,975.08.

Apr. 15—Route 3, Section 8, Camden-Clements Bridge Road, Reinforced Concrete Paving job, 3.82 miles, 36 and 40 feet wide with earth shoulders was awarded to W. Penn Corson, Camden, N. J., on his low bid of $269,644.85.

Apr. 15—Route 3, Section 9, Clements Bridge Road to Kirkwood, Reinforced Concrete Paving job, 3.756 miles, 29 feet wide with earth shoulders was awarded to John M. Kelley Construction Co., Camden, N. J., on their low bid of $200,592.95.

Apr. 15—Route 3, Section 10, Kirkwood-Berlin, Reinforced Concrete Paving job, 5.576 miles, 29 feet wide with earth shoulders was awarded to John M. Kelley Construction Co., Camden, N. J., on their low bid of $297,993.89.
Bridgeton, 1.314 miles long. Sheet Asphalt paving job on ville, Warrenite Bitulithic on Concrete base, 8 miles, 20 feet wide with gravel shoulders was awarded to the Tri-State Construction Company of Bridgeton, New Jersey, on their low bid of $455,500.12.

Apr. 18—Route 4, Section 14, Laurelton-Lakewood 3.875 miles, Reinforced Concrete Paving job, 20 feet wide with gravel shoulders was awarded to C. H. Earle of Hackensack, New Jersey, on his low bid of $144,705.68.

Apr. 19—Route 4, Section 10, Shadow Lawn-Roseld Avenue, Sheet Asphalt Paving job on Concrete Base, 2.41 miles, 20 and 36 feet wide with earth shoulders, was awarded to Newark Paving Company, of Newark, New Jersey, on their low bid of $104,969.51.

Apr. 19—Route 4, Section 12, Sea Girt Avenue, Reinforced Concrete Paving job, 0.162 miles, 20 feet wide with earth shoulders was awarded to T. H. Riddle, New Brunswick, New Jersey, on his low bid of $8,569.23.

Apr. 21—Route 9, Section 6, Somerville-Bound Brook, Reinforced Concrete Paving job, 2.491 miles, 20 feet wide, earth shoulders was awarded to Salmon Brothers, Netcong, New Jersey, on their low bid of $131,710.10.

Apr. 24—Route No. 4, Section 5-A, Storm Drain in Red Bank, was awarded to Chas. J. Romano, Montclair, New Jersey, on his low bid of $15,314.85.

Apr. 25—Route 5, Section 5, Madison Avenue, Madison Township and Borough of Madison, Warrenite Bitulithic on Concrete base, 2.032 miles, 20 feet wide with earth shoulders, was awarded to the Northern Construction Company, of Newark, New Jersey, on their low bid of $117,-844.37.

Apr. 28—Route 4, Section 13, Richmond Ave., Point Pleasant Beach, Reinforced Concrete paving job, 0.848 miles, 20 feet wide with earth shoulders was awarded to C. H. Earle of Hackensack, New Jersey, on his low bid of $35,471.76.

May 9—Route 9, Section 5, Union Avenue, Bound Brook, Sheet Asphalt on Concrete Base, 1.501 miles, 20 feet wide with earth shoulders was awarded to the Utility Construction Company of New Brunswick, New Jersey, on their low bid of $93,090.31.

May 26—Route 4, Section 15, Lakewood (County Section) 1.056 miles Reinforced Concrete Paving job, twenty-eight and thirty feet wide, was awarded to the Public Service Production Company of Newark, New Jersey, on their low bid of $75,748.82.

May 26—Route 4, Section 15, Lakewood (Township Section) 1.5 miles, Reinforced Concrete Paving job, 36 and 50 feet wide was awarded to C. H. Earle of Hackensack, New Jersey, on his low bid of $105,741.10.

May 26—Route 9, Section 8, North Branch-Somerville, 3.837 miles, Reinforced Concrete paving job, 20 feet wide with earth shoulders was awarded to Ralph Sangiovanni, on his low bid of $159,077.59.

May 26—Route 16, Section 3, Bedminster-Plukamin, 2.415 miles Reinforced Concrete paving job, 20 feet wide with earth shoulders was awarded to Ralph Sangiovanni, on his low bid of $135,648.39.

May 26—Route 4, Section 16, Main St., Toms River, 1.096 miles long, Reinforced Concrete paving job, 20, 30, 36, 38 and 56 feet wide with gravel shoulders was awarded to the Public Service Production Company of Newark, New Jersey, on their low bid of $62,864.59.

June 8—Route 5, Section 9, Barker's Corner-Hackettstown, 2.99 miles Reinforced Concrete paving job, 20 and 48 feet wide with earth shoulders was awarded to Frank J. Groman, of Bethlehem, Pennsylvania, on his low bid of $230,274.37.

June 8—Route 9, Section B, West Front Street, Plainfield, Sheet Asphalt paving job on Concrete Base, 1.929 miles, 40 and 41 feet wide, was awarded to the Union Paving Company, of Newark, New Jersey, on their low bid of $219,316.20.

June 10—Route 6, Section 12, East Commerce Street

Apr. 18—Route 15, Sections 2 and 3, Bridgeton-Mill-

Concrete Base, 20 and 32 feet wide, was awarded to E. K. Mixner Co., on their low bid of $80,422.01.

June 20—Route 2, Section 3-A, Whitehorse-Crosswicks Creek, 0.389 miles, Reinforced Concrete paving job, 30 and 40 feet wide was awarded to Daniel Klockner, of Trenton, New Jersey, on his low bid of $37,472.82.

June 21—Route 5, Section 6, Speedwell Avenue, Morristown, Warrenite Bitulithic surface on Concrete Base, 1.426 miles, 23 feet, 3½ inches wide was awarded to J. S. Geiger Sons of Newark, New Jersey, on their low bid of $144,892.74.

June 21—Route 9, Section 9, Phillipsburg-Still Valley, Reinforced Concrete paving job, 1.68 miles, 20 and 36 feet wide with earth shoulders was awarded to Crilly and Cannon of Phillipsburg, New Jersey, on their low bid of $110,345.40.

June 28—Route 1, Section 6, Trenton City Line-Nottingham Way, reinforced concrete paving job, 0.928 miles, 39 feet, six inches wide, was awarded to Rees and Taylor, of Trenton, New Jersey, on their low bid of $95,347.47.

June 28—Route 4, Section 11, Main Street, Avon, New Jersey, Warrenite Bitulithic surface on Concrete Base, 0.663 miles, 43 feet wide with earth shoulders was awarded to the East Jersey Bridge Company, of Perth Amboy, New Jersey, on their low bid of $54,814.34.

July 7—Route 4, Section 17, Barnegat, Reinforced Concrete job, 1.0 miles, 20 feet wide with gravel shoulders, was awarded to the Public Service Production Company of Newark, New Jersey, on their low bid of $43,931.94.

July 7—Route 4, Section 18, Tuckerton, Reinforced Concrete job, 1.5 miles, 20 feet wide with gravel shoulders, was awarded to the Public Service Production Company of Newark, New Jersey, on their low bid of $59,913.83.

July 11—Route No. 11, Connecting link-Route No. 10 and Route No. 12. Sheet Asphalt on Concrete Foundation, was awarded to the Franklin Construction Co., of Newark, New Jersey, on their low bid of $39,737.50.

July 13—Route 9, Section 7, Main Street, Somerville, Reinforced Concrete job, 0.497 miles, was awarded to J. L. Bachman of Linden, N. J., on his low bid of $74,180.25.

July 14—Route 16, Section 2, Mine Mount Road-Bedminster Corner, Reinforced Concrete job, 2.515 miles, was awarded to the Engineering Construction Corporation, Philadelphia, Pennsylvania, on their low bid of $166,802.65.

July 17—Route 9, Section 9-A, Still Valley-Bloomsbury, Reinforced Concrete job, 2.92 miles, was awarded to Bernard E. Tighe Construction Company of Easton, Pennsylvania, on their low bid of $127,785.84.

July 21—Route 5, Section 8, Great Meadows-Barker's Corner, Reinforced Concrete, was awarded to Salmon Bros., Netcong, New Jersey, on their low bid of $186,688.69.

July 25—Route 1, Section 13, Highland Park-Stelton Road, Warrenite Bitulithic on Concrete Base, was awarded to S. S. Thompson & Company, Incorporated, Red Bank, New Jersey, on their low bid of $305,394.61.

July 25—Route 1, Section 14, Stelton Road-Metuchen, Warrenite Bitulithic on a Concrete Base, was awarded to S. S. Thompson & Company, Incorporated, Red Bank, New Jersey, on their low bid of $344,784.65.

Aug. 9—Route 15, Section 4, Millville, Warrenite Bitulithic Surface on Concrete Base, 0.986 miles, 20 feet wide, was awarded to the Tri-State Construction Company, of Bridgeton, N. J., on their low bid of $55,796.67.

Aug. 10—Route 6, Section 14, Woodbury, Reinforced Concrete paving job, 1.505 miles, 20 feet wide and 46 feet wide, was awarded to the Public Service Production Company of Newark, N. J., on their low bid of $169,775.88.

Aug. 18—Route 10, Section 3, Little Ferry-Ridgefield, Reinforced Concrete job, 1.76 miles, 20 to 30 feet wide, was awarded to John J. McGarry, of Edgewater, N. J., on his low bid of $146,760.88.

Aug. 18—Route 10, Section 5, Hudson Street, Hackensack, Sheet Asphalt job, 1.449 miles, 20 ft. 4 in. and 42 ft. 6 in. wide, was awarded to G. M. Brewster, Tenafly, N. J., on his low bid of $140,205.49.

Aug. 18—Route 10, Section 5-A, Essex Street, Hackensack, Reinforced Concrete Paving job, 0.346 miles, 22 feet wide, was awarded to Ufheil and Phelan, Hackensack, N. J., on their low bid of $24,323.09.

Sept. 15—Route No. 7, Section 1, Corlies Ave., Neptune Township, Warrenite Bitulithic on Concrete Base, 0.949 miles, 33 feet and 38 feet wide, was awarded to the East Jersey Bridge Company, of Perth Amboy, New Jersey, on their low bid of $97,110.68.

Sept. 15—Route No. 4, Section 5-A, Maple Ave., Red Bank, Sheet Asphalt Paving job on Concrete Base, 1.308 miles, 40 feet wide was awarded to the Wm. P. McDonald Construction Company, of New York City, on their low bid of $109,560.95.

Sept. 15—Route No. 9, Section 7-A, Union Ave., Grove St., Somerville, Reinforced Concrete Paving job, 0.778 miles, 20 feet wide, was awarded to the N. J. Construction Company, of Hackensack, N. J., on their low bid of $77,549.47.

Sept. 15—Route No. 16, Section 4, Pluckamin-Somerville, Reinforced Concrete Paving job, 5.475 miles, 20 and 30 feet wide, was awarded to the Peconco Engineering & Construction Company, of New York City, on their low bid of $329,749.09.

Sept. 15—Route No. 1 and 13, connecting link through New Brunswick, Asphalt Block Pavement on Concrete base, 0.874 miles, 37.4 and 45 ft. wide, was awarded to the Utility Construction Company, of New Brunswick, on their low bid of $122,644.48.

Sept. 28—Route No. 14, Section 7, Petersburg-Greenfield, Grading and Graveling job, 1.99 miles, 20 feet wide with earth shoulders was awarded to Ross & Whelan of Trenton, N. J., on their low bid of $85,196.86.

October 11—Route No. 11, Passaic Avenue, Passaic and Clifton. National Pavement on Concrete Foundation, was awarded to P. S. Kramer, of Paterson, N. J., on his low bid of $70,983.09.

October 16—Route No. 4, Connecting link-Perth Amboy. Sheet Asphalt surface on Concrete Base, was awarded to Graham & McKeon, of Perth Amboy, N. J., on their low bid of $185,216.62.

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MONTHLY BULLETIN OF DETOURS

Adopted by the New Jersey State Highway Commission

Corrected to November 18, 1924

All detours posted with signs and blazed with "Arrows"

Note:—The traveler will find poles banded along each route of the State Highway System to correspond to the colors indicating the direction of the routes.

Blue on the posts or signs indicates that the road is running **North** and **South.**
Red shows that it lies **East** and **West.**
While **Yellow** tells you that it takes a diagonal course **Northwest and Southeast.**
Brown indicates that it takes a diagonal course **Northeast** and **Southwest.**

ROUTE NO. 1, Section 13—Highland Park-Metuchen.
Detour south-bound traffic from Route No. 1 at Metuchen over Amboy Ave. and Main St. to Bonhamtown, thence over Piscataway Road to Highland Park. North-bound traffic will be maintained through construction to overhead Pennsylvania Railroad Crossing to Middlesex Ave., Metuchen.

ROUTE NO. 4, Section 5-A—Maple Avenue, Red Bank.
Detour over Front St., and Broad Street.

ROUTE NO. 4, Section 11, Avon-by-the-sea, under construction.
No detour necessary. Traffic will go through construction

ROUTE NO. 4, Section 16—Toms River, under construction.
Detour north of Toms River over Seward Ave.,Hyer Ave. and Water St. in Toms River

ROUTE NO. 4, Section 17—Barnegat, under construction.
No detour necessary. Traffic will go through construction

ROUTE NO. 4, Section 18—Tuckerton, under construction.
No detour necessary. Traffic will go through construction.

ROUTE NO. 5, Section 6—Speedwell Ave., Morristown, under construction.
Traffic being maintained.

ROUTE NO. 5, Sections 8 & 9—Between Great Meadows and Hackettstown.
Detour at Hackettstown on Main St. to Mountain Ave. to Route No. 12, thence to Washington, Oxford Furnace, Buttzville, and Route No. 5, Belvidere and Delaware.

ROUTE NO. 6, Section 14, Broad Street, Woodbury.
Under construction from railroad crossing at north end of town to Red Bank Avenue. Detour over Westville-Glassboro Road to Cooper Street to Broad Street, Woodbury.

ROUTE NO. 6—Mantua Ave., Woodbury, between Broad St., and present improvement south of Woodbury.
No detour necessary. Traffic will go through construction.

ROUTE NO. 6, Sections 10 and 11—Under construction between Salem, Quinton and Bridgeton.
Detour from Salem through Hagersville, Hancock's Bridge, Harmersville, Canton, Gum Tree Corner, Town Hall, Kerns Corner, and Roadstown to Bridgeton.

ROUTE NO. 9, Section B—Plainfield, under construction.
Detour from Route No. 9 to Muhlenberg Place to West Second Street to Clinton Ave. to West Front St., or Route No. 9.

ROUTE NO. 9, Section 7—Under construction, Borough of Somerville.
Detour over Eastern Avenue and High Street.

ROUTE NO. 9, Section 8—Under construction between Somerville and North Branch.
No detour necessary. Traffic will go through construction.

ROUTE NO. 9, Sections 1 and 2—Under construction between Perryville and West Portal Sections 9 and 9-A. Under construction between Bloomsbury and Phillipsburg.
Detour via Clinton, Glen Gardner, Hampton, Washington, Broadway and New Village to Phillipsburg.

ROUTE NO. 10, Section 1-B—Under construction between Arcadian Way and Anderson Avenue.
Detour over Bluff Road to Anderson Avenue.

ROUTE NO. 10, Sections 3, 5 and 5-A—At Hackensack and between Hackensack and Ridgefield.
Detour just east of Saddle River on Rochelle Ave., to Passaic St., or Arcola Road to Main Street, Hackensack, to Fort Lee Turnpike to Grand Ave., Leonia, thence south over Grand Ave. to Ridgefield or North to Englewood. For points south of Ridgefield from Hackensack detour over Rochelle Ave. to Williams Ave. to Moonachie Road to Paterson Plank Road to Hudson Co. Boulevard.

ROUTE NO. 15—Between Rio Grande and Goshen, bridge construction over Biddle Creek.
Detour from Goshen to Cape May Court House and Route No. 14 to Rio Grande.

ROUTE NO. 16, Section 2—Under construction between Mine Mt. Road to Bedminster Corner.
Detour Liberty Corner Road to Liberty Corner thence to Lyons Station, and Basking Ridge to Blaziers Corner on Route No. 16.

ROUTE NO. 16, Section No. 3—Between Bedminster Corner and Pluckemin.
Detour from Route No. 16 over Far Hills-Lamington Road one and one-half miles southwesterly to first road leading in a southerly direction and parallel to Route No. 16, to Burnt Mill Road to Pluckemin.

COUNTY DETOURS

In addition to the information concerning detours on account of State Highway construction, the following information is issued to advise the public of all construction on roads within each County and also to give an account of the different detours to be used in connection with this construction work. Detours are marked with directing signs and arrows.

ATLANTIC COUNTY

Downstown-Mays Landing Road under construction. For Atlantic City and Mays Landing from Downstown detour south on Lake Road to Wheat Road; thence northeast on Wheat road to Buena and Hammonton; thence east to Egg Harbor City; thence south for Mays Landing or continue east for Atlantic City.

For Richland detour from Buena south over the Tuckahoe Road to Richland Road.

BERGEN COUNTY

River Road, Borough of East Rutherford. Detour over local streets.
Railroad Ave., Ridgefield Park. Traffic being maintained.

BURLINGTON COUNTY

Mt. Holly-Medford Road. Traffic being maintained

Chester Ave., Moorestown, under construction. Detour over Oak Ave., Stanwick Ave. to Bridgeboro Road.

CUMBERLAND COUNTY

Landis Ave, Section 1 from Carll's Corner to Salem County Line. Detour over Bridgeton Ave., and Rosenhayn Road.

ESSEX COUNTY

Central Ave., Caldwell, under construction.
Detour Mountain Avenue, Greenbrook and Pier Lane.

GLOUCESTER COUNTY

Mantua-Glassboro Road under construction. Detour at Mantua over Route No. 6 to Union St. to Wenonah and over Woodbury, Glassboro Road to Glassboro.

Delaware Street, Woodbury, under construction. Traffic being maintained.

Crown Point Road one-half mile south of Westville under construction. Detour local roads.

Chestnut Branch Bridge on Barnesboro-Sewell Road under construction. Detour from Barnesboro to Pitman via Richwood Road or to Mantua over Sewell-Mantua Road.

MERCER COUNTY

White Horse-Yardville Road under construction. Traffic being maintained.
River Road from Scudder Falls to Washington's Crossing under construction.
Traffic being maintained.

MIDDLESEX COUNTY

State Street, Perth Amboy. Traffic being maintained.

River Road between Highland Park and Bound Brook under construction. Detour over road south side of Raritan River.

MONMOUTH COUNTY

Oceanport Ave., Long Branch to Oceanport under construction. Detour via Wolff's Mill and Elkwood Park to Oceanport.

MORRIS COUNTY

Long Valley-Hunterdon County Line Road under construction. Traffic being maintained.
Passaic Ave., Chatham under construction. Detour local streets.

Main St., Wharton, under construction. Detour over Dover-Woodport Road.

PASSAIC COUNTY

Cherry Lane, Hawthorne, closed between Wagarau Road and Diamond Bridge.
Detour Lincoln Street and Washington Avenue.

SALEM COUNTY

Pennsville-Salem Road under construction. Traffic being maintained.
Elmer-Centerton Road under construction. Traffic will be maintained.

SOMERSET COUNTY

Watchung Avenue, Borough of North Plainfield, under construction.
Detour local streets

SUSSEX COUNTY

Monroe-Hamburgh Road under construction.
Detour by the way of Sussex for traffic from Franklin or Hamburg to Branchville.

Ross's Corner, Sussex Road, under construction near Sussex. Detour Beenerville Road and Branchville road.

High Street, Newton, under construction. Detour over Main St., Liberty St., Linwood Ave., Thompson St., West End Ave., and Ridge Road to first road leading to right to Fredon-Newton Road.

UNION COUNTY

Hillside Avenue, Liberty Avenue and Salem Road in Hillside and Union Townships under construction.
Detour over local streets.

Walnut Avenue between South Avenue and Lehigh Valley R. R. tracks, Cranford Township, under construction.
Detour Union Ave., Lincoln Ave., Denman Ave., Rahway Ave., and Lexington Ave.

Springfield Ave., New Providence under construction. Detour South St., and Central Ave.

Mountain Ave., Westfield, under construction. Traffic being maintained.

WARREN COUNTY

Washington-Buttsville Road under construction from Buttzville Hill to State Highway Route No. 5.
Traffic is being maintained.

Hope-Blairstown Road under construction.
Detour from Square in Hope to Yall and over Hainesburg-Blairstown Road to Blairstown.